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(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus with which highly efficient operation is possible has been demanded. An air conditioner (100) includes a first refrigerant circuit (110) and a second refrigerant circuit (120). The first refrigerant circuit includes a first compressor (10), a first heat exchanger (40) functioning as a radiator for a refrigerant, a first expansion valve (50), and a second heat exchanger (60) functioning as a heat absorber for the refrigerant. The second refrigerant circuit connects a portion between the first compressor and the first heat exchanger and a portion between the first heat exchanger and the

first expansion valve. The second refrigerant circuit includes a second compressor (20). Suction pressure of the first compressor is lower than suction pressure of the second compressor. The first compressor is a scroll compressor, and the second compressor is a rotary compressor. Alternatively, the first compressor is a scroll compressor having a first design compression ratio, and the second compressor is a scroll compressor having a second design compression ratio smaller than the first design compression ratio.

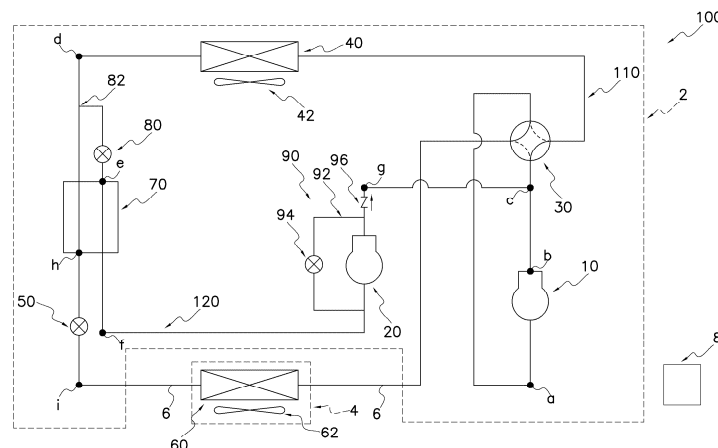


FIG. 1

Description**TECHNICAL FIELD**

5 **[0001]** The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

10 **[0002]** Conventionally, there may be cases where such a configuration has been adopted, depending on application of a refrigeration cycle apparatus or a type of a refrigerant used, for example, that, similar to a refrigeration cycle apparatus according to PTL 1 (Japanese Unexamined Patent Application Publication No. 2005-49087), a plurality of compressors are provided in a refrigerant circuit in the refrigeration cycle apparatus, the compressors are each caused to suck the refrigerant that varies in pressure, and the refrigerant compressed by each of the plurality of compressors is discharged to a single refrigerant flow path.

SUMMARY OF INVENTION

<Technical Problem>

20 **[0003]** Although, in such a refrigeration cycle apparatus as described above, efficient operation may be difficult to achieve depending on compressors selected, such a configuration of a refrigeration cycle apparatus with which highly efficient operation is possible is not disclosed in PTL 1 (Japanese Unexamined Patent Application Publication No. 2005-49087).

25 <Solution to Problem>

30 **[0004]** A refrigeration cycle apparatus according to a first aspect comprises a first refrigerant circuit and a second refrigerant circuit. The first refrigerant circuit includes a first compressor, a radiator, a first expansion valve, and a heat absorber. The second refrigerant circuit connects a portion between the first compressor and the radiator and a portion between the radiator and the first expansion valve. The second refrigerant circuit includes a second compressor. Suction pressure of the first compressor is lower than suction pressure of the second compressor.

[0005] The first compressor is a scroll compressor, and the second compressor is a rotary compressor. Alternatively, the first compressor is a scroll compressor having a first design compression ratio, and the second compressor is a scroll compressor having a second design compression ratio smaller than the first design compression ratio.

35 **[0006]** In the refrigeration cycle apparatus according to the first aspect, the second refrigerant circuit is connected to the first refrigerant circuit at the portion between the first compressor and the radiator. Therefore, the first compressor and the second compressor are identical to each other in discharge pressure. Furthermore, in the refrigeration cycle apparatus according to the first aspect, the suction pressure of the first compressor is lower than the suction pressure of the second compressor. Therefore, in the refrigeration cycle apparatus according to the first aspect, the compression ratio of the first compressor becomes greater than the compressor of the second compressor.

[0007] Using a scroll compressor that is high in efficiency in a region where the compression ratio is high as the first compressor and a rotary compressor that is high in efficiency in a region where the compression ratio is low as the second compressor makes it possible to make the refrigeration cycle apparatus highly efficient.

45 **[0008]** Also, in a case where a scroll compressor that is great in design compression ratio is used as the first compressor and a scroll compressor that is small in design compression ratio is used as the second compressor, it is possible to operate both the compressors in efficient regions, making it possible to make the refrigeration cycle apparatus highly efficient.

50 **[0009]** A refrigeration cycle apparatus according to a second aspect is the refrigeration cycle apparatus according to the first aspect, the second refrigerant circuit further includes a second expansion valve and an economizer heat exchanger disposed between the radiator and the heat absorber. The economizer heat exchanger is configured to exchange heat between the refrigerant that flows out of the radiator, is branched to the second refrigerant circuit at a branch portion, and is decompressed by the second expansion valve and the refrigerant that flows out of the radiator. The refrigerant decompressed by the second expansion valve and passing through the economizer heat exchanger is sucked into the second compressor.

55 **[0010]** In the refrigeration cycle apparatus according to the second aspect, as the refrigerant that has passed through the economizer heat exchanger is compressed by the second compressor, it is possible to achieve improvements in capability and performance.

[0011] A refrigeration cycle apparatus according to a third aspect is the refrigeration cycle apparatus according to the second aspect, the branch portion is disposed between the radiator and the economizer heat exchanger.

[0012] In the refrigeration cycle apparatus according to the third aspect, the refrigerant that has flowed out of the radiator is partially branched to the second refrigerant circuit and flows toward the economizer heat exchanger via the second expansion valve, and rest of the refrigerant flows toward the first expansion valve via the economizer heat exchanger. Therefore, with the refrigeration cycle apparatus according to the third aspect, it is possible to improve the capability of the refrigeration cycle apparatus while the economizer heat exchanger is suppressed in size, compared with a case where the refrigerant flowing out of the radiator is not branched but fully flows into the economizer heat exchanger.

[0013] A refrigeration cycle apparatus according to a fourth aspect is the refrigeration cycle apparatus according to the first aspect, the first refrigerant circuit further includes a second expansion valve. The second refrigerant circuit further includes a refrigerant vessel that is configured to separate gas and liquid. The refrigerant vessel is disposed between the radiator and the heat absorber, and into which the refrigerant that flowing out of the radiator and decompressed to be brought into a two-phase state by the second expansion valve flows. The gas refrigerant separated in the refrigerant vessel is sucked into the second compressor.

[0014] In the refrigeration cycle apparatus according to the fourth aspect, by lowering the refrigerant flowing into the heat absorber in temperature, it is possible to improve the refrigeration cycle apparatus in capability.

[0015] A refrigeration cycle apparatus according to a fifth aspect is the refrigeration cycle apparatus according to the fourth aspect, the second refrigerant circuit further includes a heat exchanger. The heat exchanger is arranged to exchange heat between the refrigerant flowing out of the radiator toward the second expansion valve and the gas refrigerant separated in the refrigerant vessel.

[0016] In the refrigeration cycle apparatus according to the fifth aspect, further using the heat exchanger makes it possible to improve the refrigeration cycle apparatus in capability.

[0017] A refrigeration cycle apparatus according to a sixth aspect is the refrigeration cycle apparatus according to any one of the second aspect to the fifth aspect, the second compressor in the second refrigerant circuit is a rotary compressor. In a case where a load is at least equal to or lower than 47%, a number of rotations of the first compressor is greater than a number of rotations of the second compressor.

[0018] In the refrigeration cycle apparatus according to the sixth aspect, under a relatively-low-load condition that is high in frequency of use (under a condition of a load of 47%, which is one condition for calculating a seasonal energy efficiency ratio (SEER)), the scroll compressor that is efficient in a region where the number of rotations is greater is operated at a greater number of rotations than the rotary compressor that is efficient in a region where the number of rotations is smaller. Thus, it is possible to achieve efficient operation.

[0019] A refrigeration cycle apparatus according to a seventh aspect is the refrigeration cycle apparatus according to the sixth aspect, in a case where a load is at least equal to or lower than 74%, the number of rotations of the first compressor is greater than the number of rotations of the second compressor.

[0020] In the refrigeration cycle apparatus according to the seventh aspect, under a wide-load condition (even under a condition of a load of 74%, which is one condition for calculating an SEER), the scroll compressor that is efficient in a region where the number of rotations is greater is operated at a greater number of rotations than the rotary compressor that is efficient in a region where the number of rotations is smaller. Thus, it is possible to achieve further efficient operation.

[0021] A refrigeration cycle apparatus according to an eighth aspect is the refrigeration cycle apparatus according to any one of the first aspect to the seventh aspect, the refrigerant filled in the first refrigerant circuit and the second refrigerant circuit contains CO₂ at least partially in its components.

[0022] In the refrigeration cycle apparatus according to the eighth aspect, a refrigerant containing at least CO₂ having a low global warming potential is used as the refrigerant, it is possible to achieve the refrigeration cycle apparatus having a low environmental load.

[0023] A refrigeration cycle apparatus according to a ninth aspect is the refrigeration cycle apparatus according to any one of the first aspect to the seventh aspect, in which the second compressor is a rotary compressor. The refrigerant filled in the first refrigerant circuit and the second refrigerant circuit is CO₂.

[0024] In the refrigeration cycle apparatus according to the ninth aspect, as CO₂ having a low global warming potential is used as the refrigerant, it is possible to achieve the refrigeration cycle apparatus having a low environmental load.

[0025] A refrigeration cycle apparatus according to a tenth aspect is the refrigeration cycle apparatus according to the ninth aspect, a ratio of displacement of the second compressor with respect to displacement of the first compressor is determined so that, in a case where a load is 47%, a number of rotations of the second compressor is greater than a minimum number of rotations at which continuous operation is possible.

[0026] In the refrigeration cycle apparatus according to the tenth aspect, suppressing the number of rotations of the second compressor (rotary compressor) as small as possible when a load is high makes it possible to achieve highly efficient operation even when the load is high. In other words, increasing the ratio of the displacement of the second compressor with respect to the displacement of the first compressor as much as possible makes it possible to maintain a refrigeration cycle high in efficiency when a load is high.

[0027] However, if such a measure is only taken that the number of rotations of the second compressor is suppressed as small as possible, the number of rotations of the second compressor may become too small and it is impossible to continue

continuous operation under a relatively-low-load condition that is high in frequency of operation (under a condition of a load of 47%, which is one condition for calculating an SEER), possibly resulting in a decrease in SEER.

[0028] In contrast, in the refrigeration cycle apparatus according to the tenth aspect, as the ratio of the displacement of the second compressor with respect to the displacement of the first compressor is determined so that the number of rotations of the second compressor is greater than the minimum number of rotations at which continuous operation is possible when a load is 47%, it is possible to suppress a decrease in SEER.

[0029] A refrigeration cycle apparatus according to an eleventh aspect is the refrigeration cycle apparatus according to the ninth aspect or the tenth aspect, a ratio of displacement of the second compressor with respect to displacement of the first compressor is determined so that, in a case where a load is 100%, a number of rotations of the second compressor is smaller than a maximum number of rotations at which continuous operation is possible.

[0030] In a case where a refrigeration cycle apparatus is designed so that the number of rotations of the second compressor exceeds the maximum number of rotations at which continuous operation is possible when a load is 100%, in a case where the load actually reaches 100%, the number of rotations of the second compressor is reduced to the maximum number of rotations to continue operation of the second compressor and insufficiency in capability is compensated by causing the first compressor to be operated at a number of rotations greater than an ideal number of rotations. In such an operation state, the refrigeration cycle apparatus may decrease in efficiency when a load is 100%.

[0031] In contrast, in the refrigeration cycle apparatus according to the eleventh aspect, as the ratio of the displacement of the second compressor with respect to the displacement of the first compressor is determined to allow the number of rotations of the second compressor to be smaller than the maximum number of rotations at which continuous operation is possible when a load is 100%, it is possible to suppress a decrease in SEER.

[0032] A refrigeration cycle apparatus according to a twelfth aspect is the refrigeration cycle apparatus according to any one of the first aspect to the eleventh aspect and further includes a bypass flow path, a valve, and a control unit. The bypass flow path connects a discharge side of the second compressor in the second refrigerant circuit and a suction side of the second compressor in the second refrigerant circuit. Alternatively, the bypass flow path connects a portion between a discharge port of the first compressor and the radiator in the first refrigerant circuit and the suction side of the second compressor in the second refrigerant circuit. The valve is disposed in the bypass flow path. The control unit is configured to control operation of the valve. The control unit is configured to open the valve when the second compressor is to be stopped.

[0033] In this refrigeration cycle apparatus, as the differential pressure between the discharge side and the suction side of the second compressor is reduced when the second compressor is stopped, it is possible to suppress an outflow of refrigerating machine oil inside the second compressor from the suction port of the second compressor due to the differential pressure.

BRIEF DESCRIPTION OF DRAWINGS

[0034]

[Fig. 1] Fig. 1 is a schematic configuration diagram of an air conditioner according to a first embodiment of a refrigeration cycle apparatus.

[Fig. 2] Fig. 2 is a schematic control block diagram of the air conditioner illustrated in Fig. 1.

[Fig. 3A] Fig. 3A is a schematic p-h diagram of an air conditioner in which no second refrigerant circuit is present (air conditioner including only a first refrigerant circuit).

[Fig. 3B] Fig. 3B is a schematic p-h diagram when cooling operation is performed in the air conditioner illustrated in Fig. 1.

[Fig. 4] Fig. 4 is a flowchart for explaining control when operation of a second compressor is to be stopped in the air conditioner illustrated in Fig. 1.

[Fig. 5] Fig. 5 is a p-h diagram schematically depicting ideally-balanced refrigeration cycles for each load.

[Fig. 6] Fig. 6 is a diagram for explaining an example of a method for determining a maximum value of a ratio of displacement of the second compressor with respect to displacement of a first compressor.

[Fig. 7] Fig. 7 is a diagram for explaining an example of a method for determining a minimum value of the ratio of the displacement of the second compressor with respect to the displacement of the first compressor.

[Fig. 8A] Fig. 8A is a schematic configuration diagram of an air conditioner according to Modification Example A.

[Fig. 8B] Fig. 8B is a schematic configuration diagram of an air conditioner according to Modification Example B.

[Fig. 8C] Fig. 8C is another example of the schematic configuration diagram of the air conditioner according to Modification Example B.

[Fig. 9] Fig. 9 is a schematic configuration diagram of an air conditioner according to Modification Example D.

[Fig. 10] Fig. 10 is a schematic configuration diagram of a cold-storage refrigeration apparatus according to a second embodiment of the refrigeration cycle apparatus.

DESCRIPTION OF EMBODIMENTS

[0035] Embodiments of a refrigeration cycle apparatus according to the present disclosure will now be described herein with reference to the accompanying drawings.

<First Embodiment>

[0036] An air conditioner 100 according to a first embodiment of the refrigeration cycle apparatus according to the present disclosure will now be described herein with reference to the accompanying drawings. Note that the refrigeration cycle apparatus according to the present disclosure is not limited to the air conditioner, and may be a device of another type (for example, a chiller), which uses a vapor compression refrigeration cycle to perform cooling or heating for a target to which a temperature is to be adjusted (medium such as air or water).

(1) Overall Configuration

[0037] An overall configuration of the air conditioner 100 will now be described herein with reference to Fig. 1. Fig. 1 is a schematic configuration diagram of the air conditioner 100.

[0038] The air conditioner 100 is a device that uses a vapor compression refrigeration cycle to perform cooling or heating of air in a room in a building, for example, representing a target to which the temperature is to be adjusted, to perform cooling or heating for the room in the building, for example. Furthermore, although the air conditioner 100 according to the present embodiment is a device capable of performing cooling and heating in a room in a building, for example, the air conditioner 100 may be a device dedicated for cooling.

[0039] As illustrated in Fig. 1, the air conditioner 100 mainly includes a first refrigerant circuit 110 and a second refrigerant circuit 120. The refrigerant circuits 110, 120 in the air conditioner 100 are filled with, but not limited to, a refrigerant containing carbon dioxide (CO₂) at least partially in its components. The refrigerant circuits 110, 120 in the air conditioner 100 are filled with a refrigerant of a single type that is carbon dioxide. Carbon dioxide serves as a refrigerant that has a low global warming potential, a low environmental load, and no toxicity or flammability, and is thus highly safe.

[0040] As illustrated in Fig. 1, the first refrigerant circuit 110 mainly includes a first compressor 10, a first heat exchanger 40, a first expansion valve 50, and a second heat exchanger 60. In the present embodiment, the first compressor 10, the first heat exchanger 40, and the first expansion valve 50 are mounted in a heat source unit 2 disposed outdoors, such as on a rooftop of the building, and the second heat exchanger 60 is mounted in a utilization unit 4 disposed in a space that is a target of air conditioning or near the space that is the target of air conditioning. In the air conditioner 100, the heat source unit 2 and the utilization unit 4 are connected to each other by refrigerant connection pipes 6 to configure the first refrigerant circuit 110.

[0041] The second refrigerant circuit 120 connects a portion between the first compressor 10 and a radiator (first heat exchanger 40) in the first refrigerant circuit 110 and a portion between the radiator (first heat exchanger 40) and the first expansion valve 50 in the first refrigerant circuit 110, in the first refrigerant circuit 110 in which the air conditioner 100 is in a state of performing cooling operation (in other words, in a state where a switching mechanism 30 connects the pipes so that the first heat exchanger 40 functions as the radiator for the refrigerant and the second heat exchanger 60 functions as a heat absorber (evaporator) for the refrigerant).

[0042] The second refrigerant circuit 120 mainly includes a second compressor 20. Furthermore, the second refrigerant circuit 120 includes a second expansion valve 80 and an economizer heat exchanger 70 disposed between the first heat exchanger 40 and the second heat exchanger 60 in the first refrigerant circuit 110. Note that the economizer heat exchanger 70 is disposed to straddle the first refrigerant circuit 110 and the second refrigerant circuit 120.

[0043] The second refrigerant circuit 120 is used to improve a refrigeration cycle in performance during the cooling operation by the air conditioner 100. Specific description will be given below.

[0044] When assuming that no second refrigerant circuit 120 is present (in other words, assuming that only the first refrigerant circuit 110 is provided), as the CO₂ refrigerant (carbon dioxide refrigerant) used in the air conditioner 100 has a relatively low refrigeration effect due to its characteristics (see a p-h diagram illustrated in Fig. 3A), an issue arises that the first compressor 10 is increased in size for acquiring high capability with only the first refrigerant circuit 110.

[0045] In contrast, in the air conditioner 100 according to the present disclosure, the second refrigerant circuit 120 is provided, and, in the economizer heat exchanger 70, the refrigerant flowing toward the second heat exchanger 60 (heat absorber) in the first refrigerant circuit 110 and the refrigerant flowing toward the second compressor 20 in the second refrigerant circuit 120 exchange heat with each other, and the refrigerant flowing toward the second heat exchanger 60 (heat absorber) in the first refrigerant circuit 110 is further cooled. Therefore, improvements in capability and performance of the air conditioner 100 are achieved, compared with a case where only the first refrigerant circuit 110 is present (see a p-h diagram illustrated in Fig. 3B).

[0046] Note that, different from the air conditioner 100 according to the present disclosure, performing intermediate

injection of the refrigerant that has passed through the economizer heat exchanger 70 into the first compressor 10, without providing the second compressor 20, also makes it possible to acquire effects of improvements in capability and performance. However, since it is possible to desirably adjust intermediate pressure in the air conditioner 100 provided with the second compressor 20, it is also possible to intentionally improve the performance of the air conditioner 100 with respect to a configuration in which intermediate injection of the refrigerant that has passed through the economizer heat exchanger 70 into the first compressor 10 is performed.

(2) Detailed Configuration

[0047] The air conditioner 100 includes a pressure equalization mechanism 90, a first fan 42, a second fan 62, and a control device 8, in addition to the first refrigerant circuit 110 and the second refrigerant circuit 120.

[0048] Various configurations of the air conditioner 100 will now be described herein in detail.

(2-1) First Refrigerant Circuit

[0049] The first refrigerant circuit 110 mainly includes the first compressor 10, the switching mechanism 30, the first heat exchanger 40, the first expansion valve 50, and the second heat exchanger 60, which are connected to each other by the pipes.

[0050] The first compressor 10 is a scroll compressor. The first compressor 10 is a compressor that is variable in operating capacity and that includes an inverter-control-type motor.

[0051] The switching mechanism 30 is a mechanism that switches a state of the first refrigerant circuit 110 between a first state (cooling operation state) and a second state (heating operation state). When the first refrigerant circuit 110 is in the first state (see solid lines in the switching mechanism 30 illustrated in Fig. 1), the first heat exchanger 40 functions as the radiator for the refrigerant, and the second heat exchanger 60 functions as the heat absorber (evaporator) for the refrigerant. When the first refrigerant circuit 110 is in the second state (see broken lines in the switching mechanism 30 illustrated in Fig. 1), the first heat exchanger 40 functions as the evaporator for the refrigerant, and the second heat exchanger 60 functions as the radiator for the refrigerant.

[0052] The switching mechanism 30 is a four-way switching valve. However, the switching mechanism 30 is not limited to the four-way switching valve, and may include a plurality of pipes and a plurality of valves to achieve those coupling states of the pipes as described below.

[0053] To set the state of the first refrigerant circuit 110 into the first state, the switching mechanism 30 connects a discharge port of the first compressor 10 and one end side of the first heat exchanger 40 to each other, and connects a suction port of the first compressor 10 and one end side of the second heat exchanger 60 to each other. Furthermore, to set the state of the first refrigerant circuit 110 into the second state, the switching mechanism 30 connects the discharge port of the first compressor 10 and the one end side of the second heat exchanger 60 to each other, and connects the suction port of the first compressor 10 and the one end side of the first heat exchanger 40 to each other.

[0054] Note that, when the air conditioner 100 is an apparatus dedicated for cooling, the air conditioner 100 may not include the switching mechanism 30.

[0055] In the first heat exchanger 40, air (heat source air) that the first fan 42 described later supplies and the refrigerant exchange heat with each other. When the state of the first refrigerant circuit 110 is the first state, the first heat exchanger 40 functions as the radiator for the refrigerant, and the refrigerant is cooled by the heat source air in the first heat exchanger 40. When the state of the first refrigerant circuit 110 is the second state, the first heat exchanger 40 functions as the heat absorber (evaporator) for the refrigerant, and the refrigerant is heated by the heat source air in the first heat exchanger 40. The first heat exchanger 40 is, for example, a fin-and-tube heat exchanger including many heat transfer tubes and many fins.

[0056] Note that the first heat exchanger 40 is not limited to a heat exchanger that allows the heat source air and the refrigerant to exchange heat with each other. The first heat exchanger 40 may be a heat exchanger that allows a medium such as water serving as a heat source and the refrigerant to exchange heat with each other.

[0057] The economizer heat exchanger 70 is disposed between the first heat exchanger 40 and the second heat exchanger 60 in the first refrigerant circuit 110, more specifically, between the first heat exchanger 40 and the first expansion valve 50 in the first refrigerant circuit 110. Furthermore, the economizer heat exchanger 70 is disposed between the second expansion valve 80 and the second compressor 20 in the second refrigerant circuit 120. During the cooling operation, the economizer heat exchanger 70 exchanges heat between the refrigerant flowing out of the radiator (first heat exchanger 40), is branched to the second refrigerant circuit 120 at a branch portion 82, and is decompressed by the second expansion valve 80 described later and the refrigerant that flows out of the radiator (first heat exchanger 40), passes through the economizer heat exchanger 70, and flows toward the heat absorber (second heat exchanger 60). As a result, during the cooling operation, the refrigerant that has been cooled in the radiator (first heat exchanger 40) and that flows toward the heat absorber (second heat exchanger 60) (see a point c and a point d illustrated in Fig. 3B) is further cooled by

the economizer heat exchanger 70 (see a point h illustrated in Fig. 3B). Note that the branch portion 82 is disposed between the first heat exchanger 40 functioning as the radiator during the cooling operation and the economizer heat exchanger 70.

[0058] The first expansion valve 50 decompresses the refrigerant flowing between the first heat exchanger 40 and the second heat exchanger 60. The first expansion valve 50 is disposed between the first heat exchanger 40 and the second heat exchanger 60, more specifically, between the economizer heat exchanger 70 and the second heat exchanger 60. The first expansion valve 50 is, for example, an electronic expansion valve that is variable in opening degree.

[0059] In the second heat exchanger 60, the refrigerant and the air in the space that is the target of air conditioning exchange heat with each other. The second heat exchanger 60 is housed in a non-illustrated housing, to which the air in the space that is the target of air conditioning is supplied by the second fan 62 disposed in the housing. In the second heat exchanger 60, the air in the space that is the target of air conditioning, which is supplied by the second fan 62, and the refrigerant exchange heat with each other. When the state of the first refrigerant circuit 110 is the first state, the second heat exchanger 60 functions as the heat absorber for the refrigerant, and the air in the space that is the target of air conditioning is cooled by the refrigerant in the second heat exchanger 60. When the state of the first refrigerant circuit 110 is the second state, the second heat exchanger 60 functions as the radiator for the refrigerant, and the air in the space that is the target of air conditioning is heated by the refrigerant in the second heat exchanger 60. The second heat exchanger 60 is, for example, a fin-and-tube heat exchanger including many heat transfer tubes and many fins.

(2-2) Second Refrigerant Circuit

[0060] The second refrigerant circuit 120 includes the second compressor 20. Furthermore, the air conditioner 100 according to the present embodiment includes the economizer heat exchanger 70 and the second expansion valve 80. The second expansion valve 80 is, for example, an electronic expansion valve that is variable in opening degree.

[0061] The second refrigerant circuit 120 is mainly used during the cooling operation (second compressor 20 is operated during the cooling operation), and is not used during heating operation. In other words, basically, the refrigerant does not flow through the second refrigerant circuit 120 during the heating operation. Therefore, below description of the flow of the refrigerant in the second refrigerant circuit 120 is given for describing the flow of the refrigerant during the cooling operation.

[0062] The second compressor 20 is a rotary compressor (including a swing compressor). The second compressor 20 is a compressor that is variable in operating capacity and that includes an inverter-control-type motor.

[0063] The economizer heat exchanger 70 is, for example, a double-pipe-type heat exchanger or a plate-type heat exchanger. As described above, during the cooling operation, the economizer heat exchanger 70 exchanges heat between the refrigerant that flows out of the radiator (first heat exchanger 40), is branched to the second refrigerant circuit 120 at the branch portion 82, and is decompressed by the second expansion valve 80 and the refrigerant that flows out of the radiator (first heat exchanger 40), passes through the economizer heat exchanger 70, and flows toward the heat absorber (second heat exchanger 60). The refrigerant that has been decompressed by the second expansion valve 80, has passed through the economizer heat exchanger 70, and has cooled the refrigerant flowing toward the heat absorber (second heat exchanger 60) is brought into a gas state, and is sucked into the second compressor 20 (see a point f illustrated in the p-h diagram illustrated in Fig. 3B).

[0064] A reason why a scroll compressor is used as the first compressor 10 and a rotary compressor is used as the second compressor 20 will now be described herein.

[0065] In the air conditioner 100, as illustrated in Fig. 3B, suction pressure of the first compressor 10 (see a point a illustrated in Fig. 3B) is lower than suction pressure of the second compressor 20 (see the point f illustrated in Fig. 3B). In contrast, since the second compressor 20 discharges the refrigerant into an area between the first compressor 10 and the first heat exchanger 40 (radiator) in the first refrigerant circuit 110, discharge pressure of the first compressor 10 (see a point b illustrated in Fig. 3B) and discharge pressure of the second compressor 20 (see a point g illustrated in Fig. 3B) are identical to each other. Therefore, a compression ratio of the first compressor 10 is higher than a compression ratio of the second compressor 20 (see Fig. 3B).

[0066] Differences in characteristics between the scroll compressor and the rotary compressor will now be described herein.

[0067] Since the scroll compressor has a structure in which compression chambers are formed in a plurality of stages in a compression mechanism, a pressure difference between each two of the compression chambers is small, and leakage of the refrigerant between each two of the compression chambers tends to be easily suppressed. Therefore, in general, high efficiency tends to be easily achieved with the scroll compressor even under a high differential pressure condition, compared with the rotary compressor. On the other hand, there is an issue in the scroll compressor that, since a design of a scroll shape of a scroll compression mechanism defines its compression ratio, there is a decrease in efficiency due to an excessive compression loss under a condition in which the compression ratio greatly falls below the design compression ratio. In short, the scroll compressor makes it possible to achieve efficient operation under a condition in which a pressure ratio is relatively high (close to the design compression ratio).

[0068] On the other hand, the rotary compressor has general characteristics that a friction loss increases and its efficiency tends to easily decrease when the number of rotations of a motor in the compressor (hereinafter simply referred to as the number of rotations of the compressor) increases, although it is possible to achieve efficient operation under an operation condition that the number of rotations is relatively small. In other words, the rotary compressor tends to easily decrease in efficiency when the number of rotations of the compressor increases for acquiring a high pressure ratio.

[0069] Therefore, in the air conditioner 100, the scroll compressor is used as the first compressor 10 that is high in compression ratio, and the rotary compressor is used as the second compressor 20 that is low in compression ratio. By adopting such a configuration as described above, efficient operation is achieved in the air conditioner 100, compared with a case where scroll compressors that are identical to each other in specifications are used for the first compressor 10 and the second compressor 20 or a case where rotary compressors are used for both the first compressor 10 and the second compressor 20.

(2-3) Pressure Equalization Mechanism

[0070] The pressure equalization mechanism 90 is a mechanism for achieving pressure equalization between the pressure on a discharge side of the second compressor 20 and the pressure on a suction side of the second compressor 20 when the second compressor 20 is stopped.

[0071] The pressure equalization mechanism 90 includes a bypass flow path 92, a bypass valve 94 (valve), and a check valve 96.

[0072] The check valve 96 is provided between a discharge port of the second compressor 20 and a coupling portion of the second refrigerant circuit 120 to the first refrigerant circuit 110 each other (coupling portion between the second refrigerant circuit 120 and a pipe coupling the discharge port of the first compressor 10 and the switching mechanism 30 to each other). The check valve 96 prevents the refrigerant from flowing from a side where the coupling portion of the second refrigerant circuit 120 and the first refrigerant circuit 110 is present to a side where the discharge port of the second compressor 20 is present. Note that, in a case where such a situation does not occur that the air conditioner 100 does not perform the heating operation (does not include the switching mechanism 30), and only the first compressor 10 is not operated in a state where the second compressor 20 is stopped, the check valve 96 may be omitted.

[0073] The bypass flow path 92 is a flow path that connects the discharge side of the second compressor 20 in the second refrigerant circuit 120 and the suction side of the second compressor 20 in the second refrigerant circuit 120. Specifically, the bypass flow path 92 connects a portion between the discharge port of the second compressor 20 and the check valve 96 in the second refrigerant circuit 120 and the suction side of the second compressor 20.

[0074] Note that, although illustrations are omitted, the bypass flow path 92 may be a flow path that connects a portion between the discharge port of the first compressor 10 in the first refrigerant circuit 110 and the radiator (first heat exchanger 40) when the air conditioner 100 performs the cooling operation and the suction side of the second compressor 20. Specifically, the bypass flow path 92 may be a flow path that connects a pipe coupling the discharge port of the first compressor 10 and the switching mechanism 30 and the suction side of the second compressor 20. Furthermore, the bypass flow path 92 may be a flow path that connects the suction side of the second compressor 20 and a portion between the portion coupling the second refrigerant circuit 120 and the first refrigerant circuit 110 (coupling portion between the second refrigerant circuit 120 and a pipe coupling the discharge port of the first compressor 10 and the switching mechanism 30) and the check valve 96.

[0075] The bypass valve 94 is a valve disposed in the bypass flow path 92. The bypass valve 94 may be an electromagnetic valve in which only opening and closing are controllable, or may be an electrically-operated valve that is variable in opening degree.

[0076] When the second compressor 20 is stopped, the bypass valve 94 is controlled to be opened by the control device 8 to be described later. As a result, pressure equalization between the discharge side of the second compressor 20 and the suction side of the second compressor 20 is achieved. The reason of why such pressure equalization is performed is that, when the second compressor 20 is a rotary compressor, refrigerating machine oil in the second compressor 20 may flow out of a suction port of the second compressor 20, due to the characteristics of the compressor, when a state continues that the pressure on the discharge side is higher than the pressure on the suction side. Specific control for the bypass valve 94 by the control device 8 will be described later.

(2-4) First Fan and Second Fan

[0077] The first fan 42 is housed inside a housing (illustrations are omitted) of the heat source unit 2, which houses the first compressor 10, the second compressor 20, the switching mechanism 30, the first heat exchanger 40, the economizer heat exchanger 70, the first expansion valve 50, the second expansion valve 80, and the bypass valve 94, for example. The first fan 42 supplies the heat source air to the first heat exchanger 40 in the first refrigerant circuit 110 and urges exchanging of heat between the refrigerant flowing through the first heat exchanger 40 and the heat source air. Although the type of the

first fan 42 is not limited, the first fan 42 is, for example, a propeller fan.

[0078] The second fan 62 is housed in the housing (illustrations are omitted) of the utilization unit 4, which houses the second heat exchanger 60, for example. The second fan 62 sucks the air from the space that is the target of air conditioning, and supplies the sucked air to the second heat exchanger 60 in the first refrigerant circuit 110 and urges exchanging of heat between the refrigerant flowing through the second heat exchanger 60 and the sucked air from the target of air conditioning. Although the type of the second fan 62 is not limited, the second fan 62 is, for example, a cross-flow fan.

(2-5) Control Device

[0079] The control device 8 is a device that controls operation of the air conditioner 100.

[0080] The control device 8 is electrically connected to the first compressor 10, the second compressor 20, the switching mechanism 30, the first expansion valve 50, the second expansion valve 80, the bypass valve 94, the first fan 42, and the second fan 62 (see Fig. 2). The control device 8 controls operation of these devices that are electrically connected to each other to control operation of the air conditioner 100.

[0081] In the present embodiment, a non-illustrated electric circuit and a non-illustrated control board mounted on the heat source unit 2 and a non-illustrated electric circuit and a non-illustrated control board mounted on the utilization unit 4 are communicably connected to each other, and cooperate with each other to function as the control device 8. Note that, in Fig. 1, for purposes of convenience, the control device 8 is illustrated at a position separated from the heat source unit 2 and the utilization unit 4, for example.

[0082] In the present embodiment, the control device 8 includes a control computation device and a memory device. As the control computation device, it is possible to use a processor such as a central processing unit (CPU). The control computation device reads a program stored in the memory device and controls operation of the air conditioner 100 according to the program.

(2-5-1) Heating Operation

[0083] To cause the air conditioner 100 to perform the heating operation, the control device 8 controls operation of the switching mechanism 30, sets the state of the first refrigerant circuit 110 into the second state, and operates the first compressor 10. The control device 8 controls a number of rotations of the motor in the first compressor 10 and the opening degree of the first expansion valve 50 based on results of measurement by various sensors (a temperature sensor for measuring a temperature of the refrigerant, a pressure sensor for measuring pressure of the refrigerant, and a temperature sensor for measuring a temperature in the space that is the target of air conditioning, for example) disposed at various positions in the air conditioner 100. Furthermore, the control device 8 operates motors of the first fan 42 and the second fan 62 each at a predetermined number of rotations.

[0084] Note that, during the heating operation, the control device 8 controls the second expansion valve 80 and the bypass valve 94 to be each in a closed state, and does not operate the second compressor 20.

(2-5-2) Cooling Operation

[0085] To cause the air conditioner 100 to perform the cooling operation, the control device 8 controls operation of the switching mechanism 30, sets the state of the first refrigerant circuit 110 into the first state, and operates the first compressor 10 and the second compressor 20. The control device 8 controls the numbers of rotations of the motors in the first compressor 10 and the second compressor 20 and the opening degrees of the first expansion valve 50 and the second expansion valve 80 based on results of measurement by the various sensors (the temperature sensor for measuring the temperature of the refrigerant, the pressure sensor for measuring the pressure of the refrigerant, and the temperature sensor for measuring the temperature in the space that is the target of air conditioning, for example) disposed at the various positions in the air conditioner 100. Furthermore, the control device 8 operates the motors of the first fan 42 and the second fan 62 each at a predetermined number of rotations.

[0086] Note that, during the cooling operation, the control device 8 controls the bypass valve 94 to be in the closed state.

(2-5-3) Pressure Equalization Control when Cooling Operation is stopped

[0087] Pressure equalization control between the discharge side and the suction side of the second compressor 20 using the pressure equalization mechanism 90 when the second compressor 20 is stopped will now be described herein with reference to a flowchart illustrated in Fig. 4. Note that, cases when the second compressor 20 is stopped include not only a case where operation of the air conditioner 100 is wholly stopped but also a case where only the second compressor 20 is stopped for some reason while operation of the first compressor 10 is continued.

[0088] The control device 8 determines whether or not to stop operation of the second compressor 20 during the cooling operation (in a state where both the first compressor 10 and the second compressor 20 are operated) (step S1). Cases of stoppage of operation of the second compressor 20 include not only a case where operation of the air conditioner 100 is wholly stopped but also a case where only the second compressor 20 is stopped while operation of the first compressor 10 is continued, as described above.

[0089] When the control device 8 determines stoppage of operation of the second compressor 20 at step S1, the control device 8 opens the bypass valve 94 (step S2).

[0090] At step S3, the control device 8 determines whether or not differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated. Whether or not the differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated is determined by, for example, comparing the pressure measured by a pressure sensor (not illustrated) provided on the discharge side of the second compressor 20 and the pressure measured by a pressure sensor (not illustrated) provided on the suction side of the second compressor 20 with each other. Note that, as for the method for determining whether or not the differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated, a method that uses a result of measurement of the pressure by the pressure sensor may not be used. For example, the control device 8 may determine whether or not the differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated based on a time from when the bypass valve 94 is opened. Specifically, the control device 8 determines that the differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated when a predetermined time has elapsed after the bypass valve 94 is opened.

[0091] When it is determined at step S3 that the differential pressure between the discharge side and the suction side of the second compressor 20 has been eliminated, the control device 8 causes the bypass valve 94 to be closed (step S4).

[0092] As a result, a possibility that the refrigerating machine oil in the second compressor 20 flows out of the suction port of the second compressor 20 is reduced.

(3) Method for Determining Ratio of Displacement of Second Compressor with respect to Displacement of First Compressor

[0093] In the air conditioner 100, the scroll compressor is used as the first compressor 10, and the rotary compressor is used as the second compressor 20 to make the air conditioner 100 highly efficient.

[0094] To further improve the air conditioner 100 in efficiency, it is preferable to appropriately determine a ratio of the displacement (displacement volume) of the second compressor 20 with respect to the displacement (displacement volume) of the first compressor 10 (hereinafter simply referred to as a displacement ratio). A method for determining a displacement ratio will now be described herein.

[0095] Seasonal energy efficiency ratio (SEER) is used as a criterion for evaluating cooling performance of the air conditioner 100. SEER is calculated by calculating efficiency under a plurality of load conditions. Specifically, SEER is calculated from efficiency under conditions including, for example, a load of 100% and an outside air temperature of 35°C (referred to as Condition A for convenience of description), a load of 74% and an outside air temperature of 30°C (referred to as Condition B for convenience of description), and a load of 47% and an outside air temperature of 25°C (referred to as Condition C for convenience of description). Therefore, to achieve the air conditioner 100 that is high in SEER, efficient operation is desired under each of the plurality of conditions. Efficiency under Condition C, which significantly influences a value of an SEER, is important for a performance evaluation of the air conditioner 100 under a relatively-low-load condition.

[0096] By determining a type of the refrigerant (in other words, determining pressure-temperature characteristics that are inherent to the refrigerant) and making some assumptions, it is possible to acquire a ratio of a circulation amount of the refrigerant in the second compressor 20 with respect to a circulation amount of the refrigerant in the first compressor 10 (referred to as a refrigerant circulation amount ratio) under Conditions A to C described above from an ideally-balanced refrigeration cycle (p-h diagram illustrated in Fig. 5). For example, a value of β / α illustrated in Fig. 5 serves as a preferable refrigerant circulation amount ratio under Condition C. As illustrated in Fig. 5, the refrigerant circulation amount ratio tends to decrease along a shift from a high-load condition to a low-load condition.

[0097] Note that the assumptions used for calculating a refrigerant circulation amount ratio described above include, for example, that the suction pressure (intermediate pressure) of the second compressor 20 represents a geometrical mean value of the discharge pressure and the suction pressure of the first compressor 10, the economizer heat exchanger 70 is a counter-flow cascade heat exchanger, each temperature difference on an outlet side is 5K, a degree of superheating of suction of the first compressor 10 is 5K, and high pressure is determined to allow a coefficient of performance (COP) to be maximum. However, assumptions to be used may be determined appropriately in consideration of, for example, actual operation conditions of the air conditioner 100.

[0098] When a refrigerant circulation amount ratio is determined, it is possible to determine a required number of rotations of each of the compressors 10 and 20 from a suction density of each of the compressors 10 and 20 and a ratio (displacement ratio) of the displacement (displacement volume) of the second compressor 20 with respect to the

displacement (displacement volume) of the first compressor 10. Since the suction density of each of the compressors 10 and 20 is determined from an ideally-balanced refrigeration cycle, determining a displacement ratio makes it possible to determine a required number of rotations of each of the compressors 10 and 20.

[0099] A method for determining an appropriate displacement ratio in view of a required number of rotations of each of the compressors 10 and 20 under each of Condition A to Condition C (in view of a required number of rotations of each of the compressors 10 and 20 under each of Conditions A and C) will now be described herein.

[0100] The second compressor 20 is the rotary compressor as described above. To acquire high efficiency in the air conditioner 100, it is preferable that the number of rotations of the second compressor 20 be as small as possible under all of Conditions A to C, from a viewpoint of the characteristics of the rotary compressor described above. Specifically, from a viewpoint of only suppressing the number of rotations of the rotary compressor, it is preferable that the number of rotations of the second compressor 20 be determined to be smaller than the number of rotations of the first compressor 10 under all of Conditions A to C, as illustrated in (a) in Fig. 6.

[0101] However, when the number of rotations of the second compressor 20 is determined in this way, there is a possibility that the number of rotations of the second compressor 20 may fall below a minimum allowable number of rotations at which continuous operation of the second compressor 20 is possible, which is determined from the specifications of the second compressor 20, under Condition C where a load is low. When such a state is attained, the air conditioner 100 under Condition C decreases in efficiency, and thus the air conditioner 100 significantly decreases in SEER.

[0102] Therefore, it is preferable that a displacement ratio be determined to allow the number of rotations of the second compressor 20 to be greater than the minimum allowable number of rotations at which continuous operation of the second compressor 20 is possible (to attain a state illustrated in (b) in Fig. 6) even under Condition C where the load is small (even when a load is 47%).

[0103] By expressing the method for determining a maximum value of the displacement ratio as an equation, Equation 1 described below is acquired.

$$\text{Displacement of the second compressor 20 / Displacement of the first compressor 10 (Displacement ratio)} \leq \text{Number of rotations of the first compressor 10 at which maximum capability (rated capability) may be exerted} \times 47\% \times 11\% \div \text{Minimum value of the number of rotations of the second compressor 20 at which normal continuous operation is possible} \quad \text{<Equation 1>}$$

[0104] Note that, here, the value of "47%" is a value of a load under Condition C, and the value of "11%" is an optimum volume-flow ratio of the first compressor 10 with respect to the second compressor 20 under temperature conditions defined in Condition C (specifically, an outside air temperature of 25°C and an evaporation temperature of 5°C), which is a value determined from physical properties of the refrigerant used in the air conditioner 100 and an ideally-balanced refrigeration cycle determined based on assumptions, as described above.

[0105] However, if a fact that continuous operation of the second compressor 20 is possible under Condition C is only focused on, there is a possibility that the number of rotations of the second compressor 20 may exceed a maximum allowable number of rotations at which continuous operation of the second compressor 20 is possible, which is determined from the specifications of the second compressor 20, under Condition A in which a load is high (see (a) in Fig. 7).

[0106] In this case, practically, continuous operation is possible when the second compressor 20 is operated at the maximum number of rotations and the first compressor 10 is operated at a number of rotations greater than an ideal number of rotations to compensate insufficiency in capability (see (b) in Fig. 7). However, when such operation is performed, there may be a decrease in efficiency under Condition A.

[0107] Therefore, it is preferable that, even under Condition A in which the load is high (when the load is 100%), a displacement ratio be determined to allow the number of rotations of the second compressor 20 to be smaller than the maximum allowable number of rotations at which continuous operation of the second compressor 20 is possible (to be in a state illustrated in (c) in Fig. 7).

[0108] By expressing the method for determining a minimum value of the displacement ratio as an equation, Equation 2 described below is acquired.

$$\text{Displacement of the second compressor 20 / Displacement of the first compressor 10 (Displacement ratio)} \geq \text{Number of rotations of the first compressor 10 at which Maximum capability (rated capability) may be exerted} \times 28\% \div \text{Maximum value of the number of rotations of the second compressor 20 at which normal continuous operation is possible} \quad \text{<Equation 2>}$$

[0109] Note that, in here, the value of "28%" is an optimum volume-flow ratio of the first compressor 10 with respect to the second compressor 20 under temperature conditions defined in Condition A (specifically, an outside air temperature of

35°C and an evaporation temperature of 0°C), which is a value determined from the physical properties of the refrigerant used in the air conditioner 100 and an ideally-balanced refrigeration cycle determined based on assumptions, as described above.

[0110] Note that, although it is preferable that the number of rotations of the second compressor 20 be smaller than the number of rotations of the first compressor 10 under all of Conditions A to C, as described above, the number of rotations of the second compressor 20 may be greater than the number of rotations of the first compressor 10 in a region where a load is high, as illustrated in (c) in Fig. 7 (at least under Condition A in the example illustrated in (c) in Fig. 7), when the air conditioner 100 is designed to satisfy the Equation 1 and Equation 2 described above and to suppress the second compressor 20 in size as much as possible by taking into consideration a cost. However, since a degree of contribution of Condition A to a value of an SEER is relatively small (in other words, since a period of time in which the air conditioner 100 is operated under a high-load condition such as Condition A in a year is not so long), the air conditioner 100 tends to be easily maintained high in SEER even with such a design as described above has been taken.

[0111] However, since it is preferable that the number of rotations of the second compressor 20 (rotary compressor) be suppressed as much as possible from a viewpoint of the efficiency of the air conditioner 100 (since the period of time in which the air conditioner 100 is operated under a low-load condition such as Condition C is relatively long), it is preferable that the number of rotations of the first compressor 10 be greater than the number of rotations of the second compressor 20 at least when a load is equal to or lower than 47% (at least under Condition C). Furthermore, it is more preferable that the number of rotations of the first compressor 10 be greater than the number of rotations of the second compressor 20 when a load is at least equal to or smaller than 74% (at least under Condition B).

(4) Features

[0112] Features of the air conditioner 100 in a state where the air conditioner 100 performs the cooling operation will now be described herein.

[0113] (4-1)

The air conditioner 100 according to the example of the refrigeration cycle apparatus includes the first refrigerant circuit 110 and the second refrigerant circuit 120. The first refrigerant circuit 110 includes the first compressor 10, the first heat exchanger 40 functioning as a radiator for a refrigerant, the first expansion valve 50, and the second heat exchanger 60 functioning as a heat absorber for the refrigerant. The second refrigerant circuit 120 connects a portion between the first compressor 10 and the first heat exchanger 40 and a portion between the first heat exchanger 40 and the first expansion valve 50. The second refrigerant circuit 120 includes the second compressor 20. Suction pressure of the first compressor 10 is lower than suction pressure of the second compressor 20. The first compressor 10 is a scroll compressor, and the second compressor is a rotary compressor.

[0114] In the air conditioner 100, in which the second refrigerant circuit 120 is connected to the first refrigerant circuit 110 at the portion between the first compressor 10 and the first heat exchanger 40. Therefore, the first compressor 10 and the second compressor 20 are identical to each other in discharge pressure. Furthermore, in the air conditioner 100, the suction pressure of the first compressor 10 is lower than the suction pressure of the second compressor. Therefore, in the air conditioner 100, the compression ratio of the first compressor 10 becomes greater than the compressor of the second compressor 20.

[0115] Using a scroll compressor that is high in efficiency in a region where the compression ratio is great as the first compressor 10 and a rotary compressor that is high in efficiency in a region where the compression ratio is small as the second compressor 20 makes it possible to make the air conditioner 100 highly efficient.

[0116] (4-2)

In the air conditioner 100, the second refrigerant circuit 120 includes the second expansion valve 80 and the economizer heat exchanger 70 disposed between the first heat exchanger 40 and the second heat exchanger 60. The economizer heat exchanger 70 exchanges heat between the refrigerant that flows out of the first heat exchanger 40, is branched to the second refrigerant circuit 120 at the branch portion 82, and is decompressed by the second expansion valve 80 and the refrigerant that flows out of the first heat exchanger 40. The refrigerant decompressed by the second expansion valve 80 and passing through the economizer heat exchanger 70 is sucked into the second compressor 20.

[0117] In this air conditioner 100, as the refrigerant that has passed through the economizer heat exchanger 70 is compressed by the second compressor 20, it is possible to achieve improvements in capability and performance.

[0118] (4-3)

In the air conditioner 100, the branch portion 82 is disposed between the first heat exchanger 40 and the economizer heat exchanger 70.

[0119] In this air conditioner 100, the refrigerant that has flowed out of the first heat exchanger 40 is partially branched to the second refrigerant circuit 120 and flows toward the economizer heat exchanger 70 via the second expansion valve 80, and rest of the refrigerant flows toward the first expansion valve 50 via the economizer heat exchanger 70. Therefore, with the air conditioner 100, it is possible to improve the capability of the air conditioner 100 while the economizer heat

exchanger 70 is suppressed in size, compared with a case where the refrigerant flowing out of the first heat exchanger 40 is not branched but fully flows into the economizer heat exchanger 70.

[0120] (4-4)

In the air conditioner 100, it is preferable that, in a case where a load is at least equal to or lower than 47%, the number of rotations of the first compressor 10 be greater than the number of rotations of the second compressor 20.

[0121] In this air conditioner 100, under a relatively-low-load condition that is high in frequency of use (under a condition of a load of 47%, which is one condition for calculating an SEER), the scroll compressor (first compressor 10) that is efficient in a region where the number of rotations is greater is operated at a greater number of rotations than the rotary compressor (second compressor 20) that is efficient in a region where the number of rotations is smaller. Thus, it is possible to achieve efficient operation.

[0122] In the air conditioner 100, it is more preferable that, in a case where a load is at least equal to or lower than 74%, the number of rotations of the first compressor 10 be greater than the number of rotations of the second compressor 20.

[0123] In this air conditioner 100, under a wide-load condition (even under a condition of a load of 74%, which is one condition for calculating an SEER), the scroll compressor (first compressor 10) that is efficient in a region where the number of rotations is greater is operated at a greater number of rotations than the rotary compressor (second compressor 20) that is efficient in a region where the number of rotations is smaller. Thus, it is possible to achieve further efficient operation.

[0124] (4-5)

In the air conditioner 100, the refrigerant filled in the first refrigerant circuit 110 and the second refrigerant circuit 120 contains CO₂ at least partially in its components.

[0125] In the air conditioner 100 according to the embodiment described above, the refrigerant filled in the first refrigerant circuit 110 and the second refrigerant circuit 120 is CO₂.

[0126] In the air conditioner 100, CO₂ having a small global warming potential is used as the refrigerant, it is possible to achieve the air conditioner 100 having a small environmental load.

[0127] (4-6)

In the air conditioner 100, a ratio of the displacement of the second compressor with respect to the displacement of the first compressor 10 is determined so that, in a case where a load is 47%, a number of rotations of the second compressor to be greater than a minimum number of rotations at which continuous operation is possible.

[0128] In this air conditioner 100, suppressing the number of rotations of the second compressor 20 (rotary compressor) as small as possible when a load is high makes it possible to achieve highly efficient operation even when the load is high. In other words, increasing the ratio of the displacement of the second compressor 20 with respect to the displacement of the first compressor 10 as much as possible makes it possible to maintain a refrigeration cycle high in efficiency when a load is high.

[0129] However, if such a measure is only taken that the number of rotations of the second compressor 20 is suppressed as small as possible, the number of rotations of the second compressor 20 may become too small and it is impossible to continue continuous operation under a relatively-low-load condition that is high in frequency of operation (under a condition of a load of 47%, which is one condition for calculating an SEER), possibly resulting in a decrease in SEER.

[0130] In contrast, with this air conditioner 100, in which the ratio of the displacement of the second compressor 20 with respect to the displacement of the first compressor 10 is determined so that the number of rotations of the second compressor 20 is greater than the minimum number of rotations at which continuous operation is possible when a load is 47%, it is possible to suppress a decrease in SEER.

[0131] (4-7)

In the air conditioner 100, a ratio of the displacement of the second compressor 20 with respect to the displacement of the first compressor 10 is determined so that, in a case where a load is 100%, a number of rotations of the second compressor 20 is smaller than a maximum number of rotations at which continuous operation is possible.

[0132] In a case where an air conditioner 100 is designed so that the number of rotations of the second compressor 20 exceeds the maximum number of rotations at which continuous operation is possible when a load is 100%, the number of rotations of the second compressor 20 is reduced to the maximum number of rotations to continue operation of the second compressor 20 when the load actually reaches 100%, and insufficiency in capability is compensated by causing the first compressor 10 to be operated at a number of rotations greater than an ideal number of rotations. In such an operation state, the air conditioner 100 may decrease in efficiency when a load is 100%.

[0133] In contrast, with this air conditioner 100, in which the ratio of the displacement of the second compressor 20 with respect to the displacement of the first compressor 10 is determined to allow the number of rotations of the second compressor 20 to be smaller than the maximum number of rotations at which continuous operation is possible when a load is 100%, it is possible to suppress a decrease in SEER.

[0134] (4-8)

The air conditioner 100 includes the bypass flow path 92, the bypass valve 94 serving as an example of a valve, and the control device 8 serving as an example of a control unit. The bypass flow path 92 connects the discharge side of the second

compressor 20 in the second refrigerant circuit 120 and the suction side of the second compressor 20 in the second refrigerant circuit 120. Alternatively, the bypass flow path 92 connects a portion between the discharge port of the first compressor 10 and the first heat exchanger 40 in the first refrigerant circuit 110 and the suction side of the second compressor 20 in the second refrigerant circuit 120. The bypass valve 94 is disposed in the bypass flow path 92. The control device 8 controls operation of the bypass valve 94. The control device 8 allows the bypass valve 94 to be opened when the second compressor 20 is to be stopped.

[0135] In this air conditioner 100, as the differential pressure between the discharge side and the suction side of the second compressor 20 is reduced when the second compressor 20 is stopped, it is possible to suppress an outflow of the refrigerating machine oil inside the second compressor 20 that is the rotary compressor from the suction port of the second compressor 20 due to the differential pressure.

(5) Modification Examples

[0136] Modification examples of the air conditioner 100 according to the embodiment described above will now be described herein. Note that it is possible to appropriately combine the modification examples described below.

(5-1) Modification Example A

[0137] In the embodiment described above, although the branch portion 82 at which branching occurs from the first refrigerant circuit 110 to the second refrigerant circuit 120 is disposed between the first heat exchanger 40 functioning as the radiator during the cooling operation and the economizer heat exchanger 70, the present disclosure is not limited to such an aspect.

[0138] As illustrated in Fig. 8A, a branch portion 82a may be disposed between the economizer heat exchanger 70 and the second heat exchanger 60 used as the heat absorber during the cooling operation. However, in this case, as the whole refrigerant flowing out of the first heat exchanger 40 flows through the economizer heat exchanger 70 on the side where the first refrigerant circuit 110 is present, and then the refrigerant partially branches and then flows into the second refrigerant circuit 120, possibly causing the economizer heat exchanger 70 to be large in size, compared with that according to the embodiment described above.

(5-2) Modification Example B

[0139] In the embodiment described above, although the economizer heat exchanger 70 is provided in the second refrigerant circuit 120 (to straddle the first refrigerant circuit 110 and the second refrigerant circuit 120), the present disclosure is not limited to such an aspect.

[0140] As illustrated in Fig. 8B, the second refrigerant circuit 120 may include a refrigerant vessel 72 (flash tank economizer) that is gas-liquid separable and that straddles the first refrigerant circuit 110 and the second refrigerant circuit 120, instead of the economizer heat exchanger 70. Then, a second expansion valve 84 may be provided in the first refrigerant circuit 110, instead of providing the second expansion valve 80 in the second refrigerant circuit 120. Note that, although illustrations are omitted, when the air conditioner 100 is one that performs the heating operation, it is preferable that a valve (for example, an electromagnetic valve controlled by the control device 8 during the heating operation) for preventing the refrigerant from flowing is provided between the refrigerant vessel 72 and the second compressor 20 in the second refrigerant circuit 120 to prevent the refrigerant from flowing through the second refrigerant circuit 120 during the heating operation.

[0141] To describe a state where the air conditioner 100 performs the cooling operation, the refrigerant vessel 72 is disposed between the first heat exchanger 40 functioning as the radiator for the refrigerant and the second heat exchanger 60 functioning as the heat absorber for the refrigerant (more specifically, between the first heat exchanger 40 and the first expansion valve 50). The second expansion valve 84 is disposed between the first heat exchanger 40 functioning as the radiator and the refrigerant vessel 72. The refrigerant flowed out of the first heat exchanger 40 and decompressed and brought into a two-phase state by the second expansion valve 84 flows into the refrigerant vessel 72. The gas refrigerant separated in the refrigerant vessel 72 is sucked into the second compressor 20. Note that, also in this air conditioner 100, the second compressor 20 is not operated during the heating operation.

[0142] Even in such a configuration, it is possible to lower the temperature of the refrigerant flowing into the second heat exchanger 60 functioning as the heat absorber for the refrigerant during the cooling operation, making it possible to improve the capability of the air conditioner 100.

[0143] Furthermore, as illustrated in Fig. 8C, the second refrigerant circuit 120 may include, in addition to the refrigerant vessel 72, a heat exchanger 70b (economizer heat exchanger) that is disposed between and that straddles the first refrigerant circuit 110 and the second refrigerant circuit 120. The heat exchanger 70b is disposed, in the first refrigerant circuit 110, between the first heat exchanger 40 functioning as the radiator for the refrigerant during the cooling operation

and the second expansion valve 84. The heat exchanger 70b is arranged so that the refrigerant flowing out of the first heat exchanger 40 toward the second expansion valve 84 and the gas refrigerant separated in the refrigerant vessel 72 to exchange heat with each other. In the heat exchanger 70b, the refrigerant that has exchanged heat with the refrigerant flowing through the first refrigerant circuit 110 is sucked into the second compressor 20. Also in this air conditioner 100, the second compressor 20 is not operated during the heating operation.

[0144] Note that, although illustrations are omitted, also in here, when the air conditioner 100 is one that performs the heating operation, it is preferable that a valve (for example, an electromagnetic valve controlled by the control device 8 during the heating operation) for preventing the refrigerant from flowing is provided between the refrigerant vessel 72 and the heat exchanger 70b in the second refrigerant circuit 120 to prevent the refrigerant from flowing through the second refrigerant circuit 120 during the heating operation.

[0145] With this configuration, further using the heat exchanger 70b makes it possible to further improve the capability of the air conditioner 100 during the cooling operation, compared with that of the configuration illustrated in Fig. 8B.

(5-3) Modification Example C

[0146] In the embodiment described above, the scroll compressor is used as the first compressor 10, and the rotary compressor is used as the second compressor 20 to make the air conditioner 100 highly efficient.

[0147] However, the present disclosure is not limited to the configuration of the embodiment described above, and the first compressor 10 may be a scroll compressor having a first design compression ratio, and the second compressor 20 may be a scroll compressor having a second design compression ratio smaller than the first design compression ratio.

[0148] As described above, in the air conditioner 100, the compression ratio of the second compressor 20 is smaller than the compression ratio of the first compressor 10. Therefore, when a scroll compressor that is greater in design compression ratio is used as the first compressor 10 and a scroll compressor that is smaller in design compression ratio is used as the second compressor 20, it is possible to operate both the compressors 10 and 20 each in an efficient region, making it possible to make the refrigeration cycle apparatus highly efficient.

(5-4) Modification Example D

[0149] In the embodiment described above, the bypass valve 94 of the pressure equalization mechanism 90 is opened when the second compressor 20 is stopped to achieve pressure equalization between the discharge side and the suction side of the second compressor 20.

[0150] However, as illustrated in Fig. 9, the bypass flow path 92 and the bypass valve 94 for the pressure equalization mechanism 90 may not be provided. Even in the configuration as illustrated in Fig. 9, as the control device 8 opens, when the second compressor 20 is stopped, the second expansion valve 80 (for example, to an opening degree close to full opening) and allows the second expansion valve 80 to be maintained in an opened state for a predetermined period in accordance with, for example, the flowcharts illustrated in Fig. 4 (bypass valve 94 is replaced with the second expansion valve 80), it is possible to allow the pressure on the suction side of the second compressor 20 to approach the pressure on the discharge side of the second compressor 20.

(5-5) Modification Example E

[0151] Although, in the embodiment described above, the description has been given with reference to, as an example, the case where the second compressor 20 is operated during the cooling operation, the second compressor 20 may be operated during the heating operation. In other words, the second compressor 20 may be operated when the first heat exchanger 40 functions as the heat absorber and the second heat exchanger 60 functions as the radiator. Applying such a configuration as described above makes it possible to improve the air conditioner 100 in capability and performance even during the heating operation.

<Second Embodiment>

[0152] The configuration in which a scroll compressor is used as the first compressor 10 and a rotary compressor is used as the second compressor 20 and the configuration in which a scroll compressor having a first design compression ratio is used as the first compressor 10 and a scroll compressor having a second design compression ratio smaller than the first design compression ratio is used as the second compressor 20 are also useful when each of the configurations is applied to a refrigeration cycle apparatus (cold-storage refrigeration apparatus 200) having a configuration as illustrated in Fig. 10.

[0153] As illustrated in Fig. 10, the cold-storage refrigeration apparatus 200 includes a first compressor 210, a second compressor 220, a first heat exchanger 240, a freezing-purpose expansion valve 250a, a refrigeration-purpose expansion valve 250b, a freezing-purpose heat exchanger 260a, and a refrigeration-purpose heat exchanger 260b.

[0154] The cold-storage refrigeration apparatus 200 includes a first refrigerant circuit 200a including the first compressor 210, the first heat exchanger 240 serving as a radiator, the freezing-purpose expansion valve 250a serving as a first expansion valve, and a freezing-purpose heat exchanger 260a serving as a heat absorber. Furthermore, the cold-storage refrigeration apparatus 200 includes a second refrigerant circuit 200b that connects a portion between the first compressor 210 and the first heat exchanger 240 and a portion between the first heat exchanger 240 and the freezing-purpose expansion valve 250a. The second refrigerant circuit 200b includes the second compressor 220. Furthermore, the second refrigerant circuit 200b further includes the refrigeration-purpose expansion valve 250b and the refrigeration-purpose heat exchanger 260b.

[0155] The first heat exchanger 240 functions as the radiator for the refrigerant, in which a medium such as water serving as a heat source or heat source air and the refrigerant exchange heat with each other.

[0156] The freezing-purpose heat exchanger 260a is used for a purpose of cooling inside a freezer, and the refrigeration-purpose heat exchanger 260b is used for a purpose of cooling inside a refrigerator. The freezing-purpose expansion valve 250a is used to perform adjustments in pressure and flow rate of the refrigerant delivered to the freezing-purpose heat exchanger 260a. The refrigeration-purpose expansion valve 250b is used to perform adjustments in pressure and flow rate of the refrigerant delivered to the refrigeration-purpose heat exchanger 260b.

[0157] Since the freezing-purpose heat exchanger 260a and the refrigeration-purpose heat exchanger 260b differ in purpose from each other (differ in required temperatures of the refrigerant from each other), the evaporation pressure in the freezing-purpose heat exchanger 260a is lower than the evaporation pressure in the refrigeration-purpose heat exchanger 260b. Therefore, the suction pressure of the first compressor 210 is lower than the suction pressure of the second compressor 220. In other words, the compression ratio and differential pressure between the discharge pressure and the suction pressure in the second compressor 220 are small, compared with the compression ratio and differential pressure between the discharge pressure and the suction pressure in the first compressor 210. This feature is identical or similar to a relationship between the compression ratio and differential pressure between the discharge pressure and the suction pressure in the second compressor 20 and the compression ratio and differential pressure between the discharge pressure and the suction pressure in the first compressor 10 in the first embodiment.

[0158] Therefore, also in the cold-storage refrigeration apparatus 200 according to the second embodiment, the configuration in which a scroll compressor is used as the first compressor 210 and a rotary compressor is used as the second compressor 220 and the configuration in which a scroll compressor having a first design compression ratio is used as the first compressor 210 and a scroll compressor having a second design compression ratio smaller than the first design compression ratio is used as the second compressor 220 are also useful.

[0159] Note that, although illustrations and descriptions are omitted, when a rotary compressor is used as the second compressor 220, in the cold-storage refrigeration apparatus 200, the pressure equalization mechanism 90 described in the embodiment described above may be provided for the second compressor 220, and the bypass valve may be opened for a predetermined period of time when the second compressor 220 is to be stopped or the refrigeration-purpose expansion valve 250b may be opened fully for a predetermined period of time (instead of providing the pressure equalization mechanism 90).

<Note>

[0160] While the embodiments of the present disclosure have been described above, it will be understood that various changes in form and detail may be made therein without departing from the spirit and scope of the present disclosure as set forth in the appended claims.

REFERENCE SIGNS LIST

[0161]

8	control device (control unit)
10	first compressor
20	second compressor
40	first heat exchanger (radiator)
50	first expansion valve
60	second heat exchanger (heat absorber)
70	economizer heat exchanger
70b	heat exchanger
72	refrigerant vessel
80	second expansion valve
82	branch portion

- 84 second expansion valve
- 92 bypass flow path
- 94 bypass valve (valve)
- 100 air conditioner (refrigeration cycle apparatus)
- 5 110 first refrigerant circuit
- 120 second refrigerant circuit
- 200 cold-storage refrigeration apparatus (refrigeration cycle apparatus)
- 210 first compressor
- 220 second compressor
- 10 240 first heat exchanger (radiator)
- 250a freezing-purpose expansion valve (first expansion valve)
- 260a freezing-purpose heat exchanger (heat absorber)

CITATION LIST

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PATENT LITERATURE

[0162] PTL 1: Japanese Unexamined Patent Application Publication No. 2005-49087

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Claims

1. A refrigeration cycle apparatus (100, 200) comprising:

- 25 a first refrigerant circuit (110, 200a) including a first compressor (10, 210), a radiator (40, 240), a first expansion valve (50, 250a), and a heat absorber (60, 260a); and
- a second refrigerant circuit (120, 200b) that connects a portion between the first compressor and the radiator and a portion between the radiator and the first expansion valve, the second refrigerant circuit including a second compressor (20, 220),
- 30 suction pressure of the first compressor being lower than suction pressure of the second compressor, wherein
- the first compressor is a scroll compressor, and the second compressor is a rotary compressor
- or
- the first compressor is a scroll compressor having a first design compression ratio, and the second compressor is
- 35 a scroll compressor having a second design compression ratio smaller than the first design compression ratio.

2. The refrigeration cycle apparatus (100) according to claim 1, wherein

- 40 the second refrigerant circuit (120) further includes a second expansion valve (80) and an economizer heat exchanger (70) disposed between the radiator (40) and the heat absorber (60),
- the economizer heat exchanger is configured to exchange heat between the refrigerant that flows out of the radiator, is branched to the second refrigerant circuit at a branch portion (82), and is decompressed by the second expansion valve and the refrigerant that flows out of the radiator, and
- 45 the refrigerant decompressed by the second expansion valve and passing through the economizer heat exchanger is sucked into the second compressor (20).

3. The refrigeration cycle apparatus according to claim 2, wherein the branch portion is disposed between the radiator and the economizer heat exchanger.

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4. The refrigeration cycle apparatus (100) according to claim 1, wherein

- the first refrigerant circuit (110) further includes a second expansion valve (84),
- the second refrigerant circuit (120) further includes a refrigerant vessel (72) that is configured to separate gas and liquid, the refrigerant vessel being disposed between the radiator (40) and the heat absorber (60), into which the
- 55 refrigerant flowing out of the radiator and decompressed to be brought into a two-phase state by the second expansion valve flows, and
- the gas refrigerant separated in the refrigerant vessel is sucked into the second compressor (20).

5. The refrigeration cycle apparatus according to claim 4, wherein

the second refrigerant circuit further includes a heat exchanger (70b)
the heat exchanger is arranged to exchange heat between the refrigerant flowing out of the radiator toward the
second expansion valve and the gas refrigerant separated in the refrigerant vessel.

6. The refrigeration cycle apparatus according to any one of claims 2 to 5, wherein

the second compressor is a rotary compressor, and,
in a case where a load is at least equal to or lower than 47%, a number of rotations of the first compressor (10) is
greater than a number of rotations of the second compressor.

7. The refrigeration cycle apparatus according to claim 6, wherein, in a case where the load is at least equal to or lower
than 74%, the number of rotations of the first compressor is greater than the number of rotations of the second
compressor.

8. The refrigeration cycle apparatus (100, 200) according to any one of claims 1 to 7, wherein the refrigerant filled in the
first refrigerant circuit (110, 200a) and the second refrigerant circuit (120, 200b) contains CO₂ at least partially in its
components.

9. The refrigeration cycle apparatus according to any one of claims 1 to 7 wherein

the second compressor is a rotary compressor, and
the refrigerant filled in the first refrigerant circuit (110) and the second refrigerant circuit is CO₂.

10. The refrigeration cycle apparatus according to claim 9, wherein a ratio of displacement of the second compressor with
respect to displacement of the first compressor (10) is determined so that, in a case where a load is 47%, a number of
rotations of the second compressor is greater than a minimum number of rotations at which continuous operation is
possible.

11. The refrigeration cycle apparatus according to claim 9 or 10, wherein a ratio of displacement of the second compressor
with respect to displacement of the first compressor (10) is determined so that, in a case where a load is 100%, a
number of rotations of the second compressor is smaller than a maximum number of rotations at which continuous
operation is possible.

12. The refrigeration cycle apparatus (100) according to any one of claims 1 to 11, further comprising

a bypass flow path (92) connecting a discharge side of the second compressor (20) in the second refrigerant
circuit (120) or a portion between a discharge port of the first compressor (10) and the radiator (40) in the first
refrigerant circuit (110) and a suction side of the second compressor in the second refrigerant circuit;
a valve (94) disposed in the bypass flow path; and
a control unit (8) configured to control operation of the valve,
wherein
the control unit is configured to open the valve when the second compressor is to be stopped.

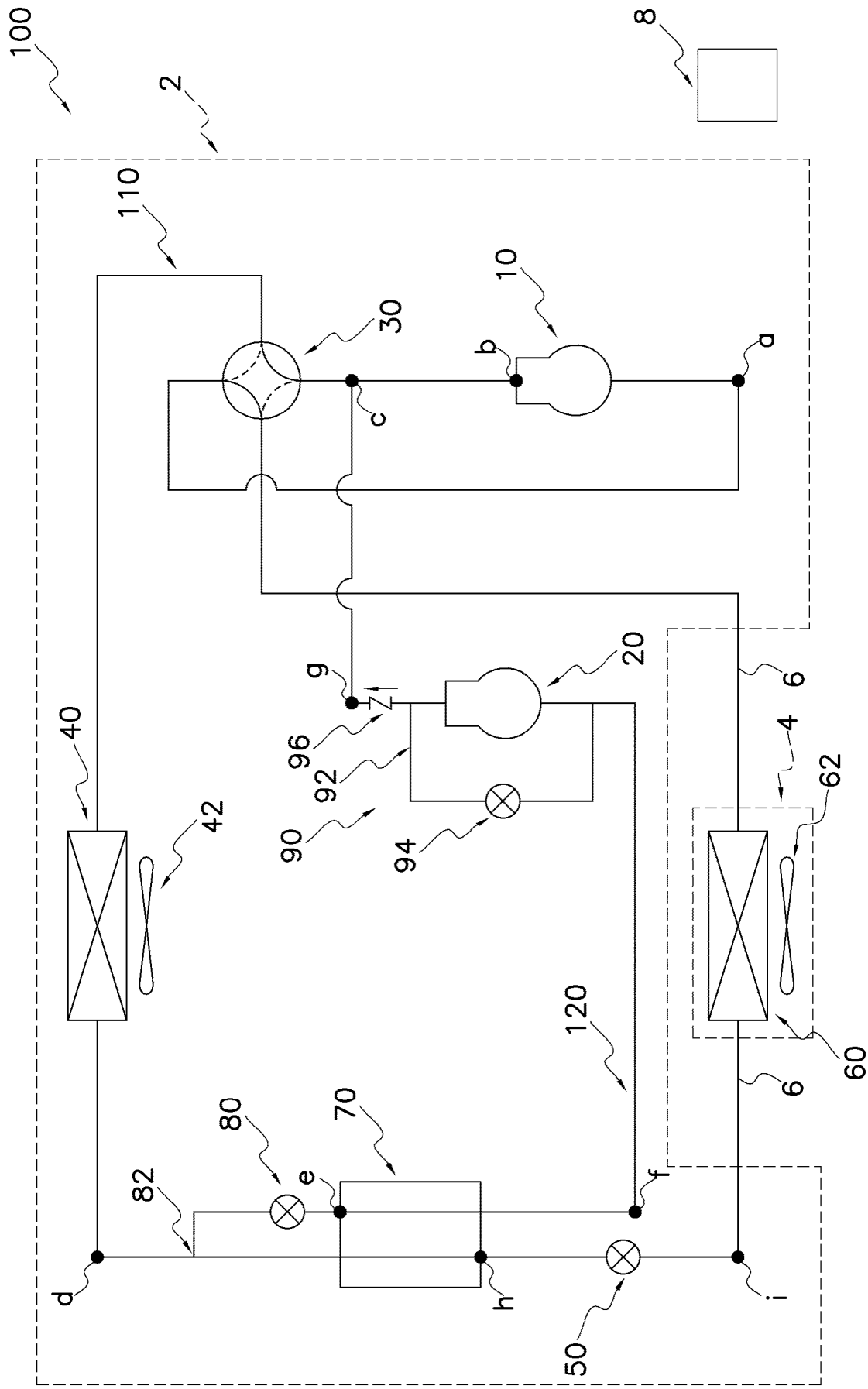


FIG. 1

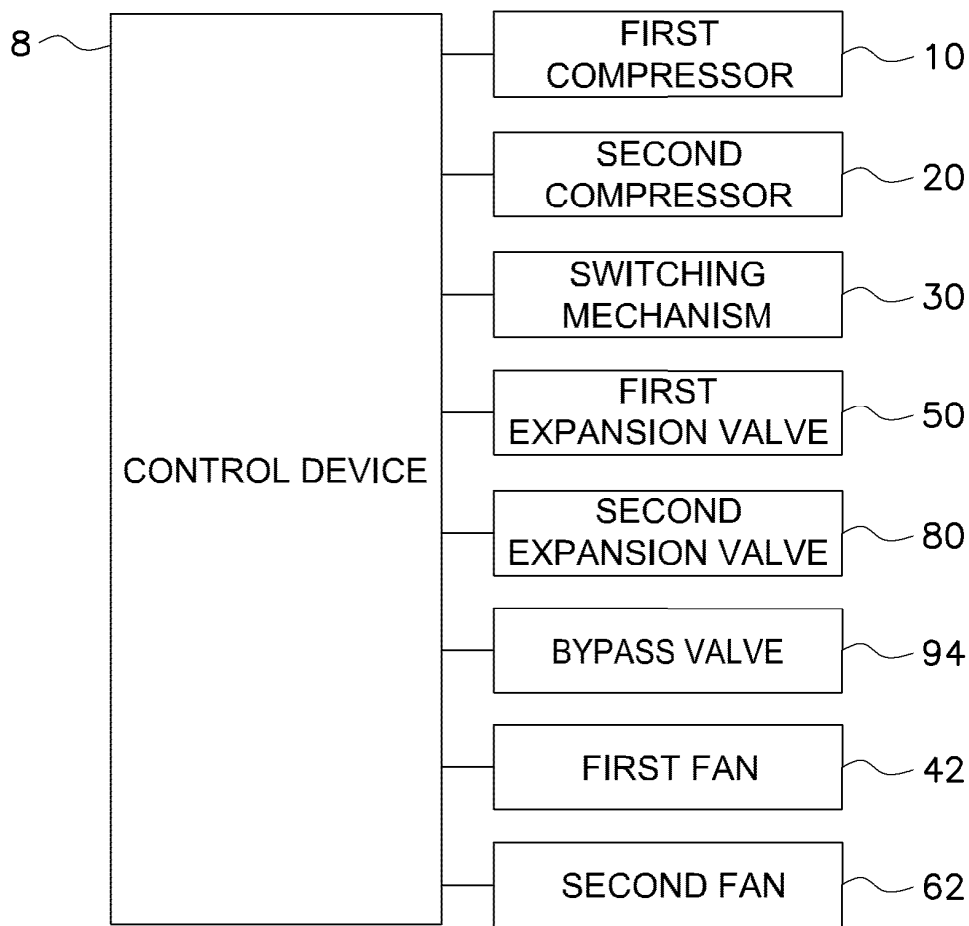


FIG. 2

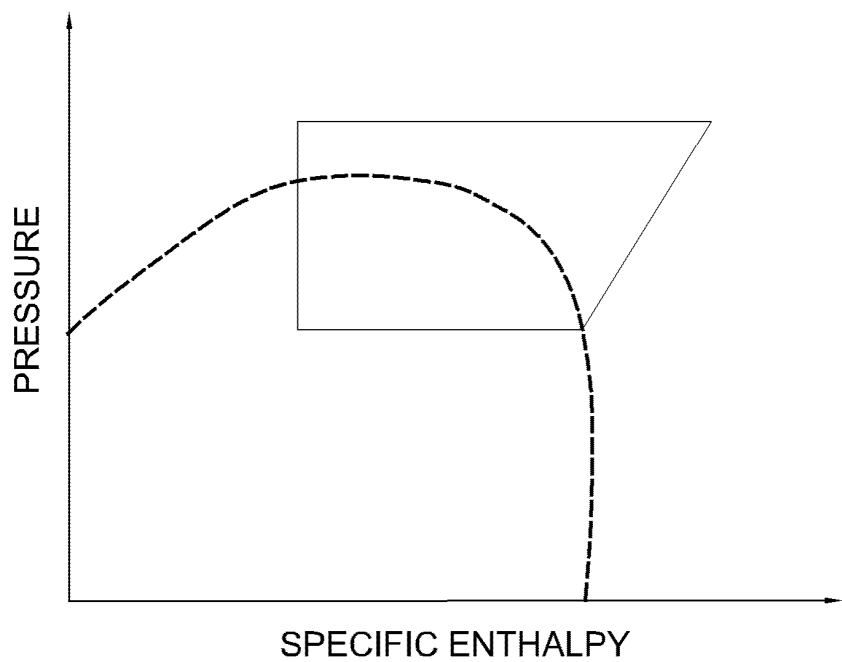


FIG. 3A

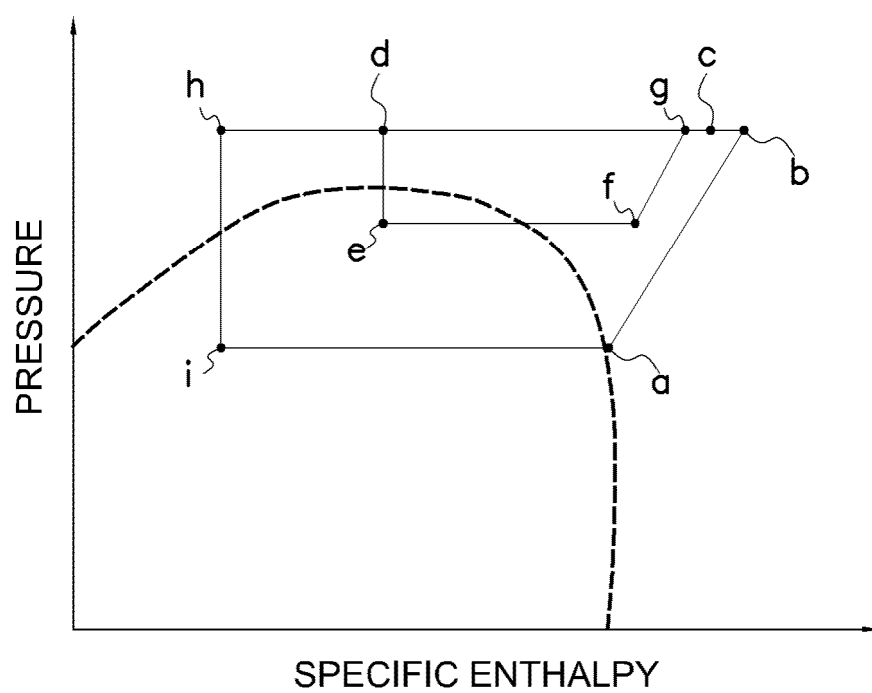


FIG. 3B

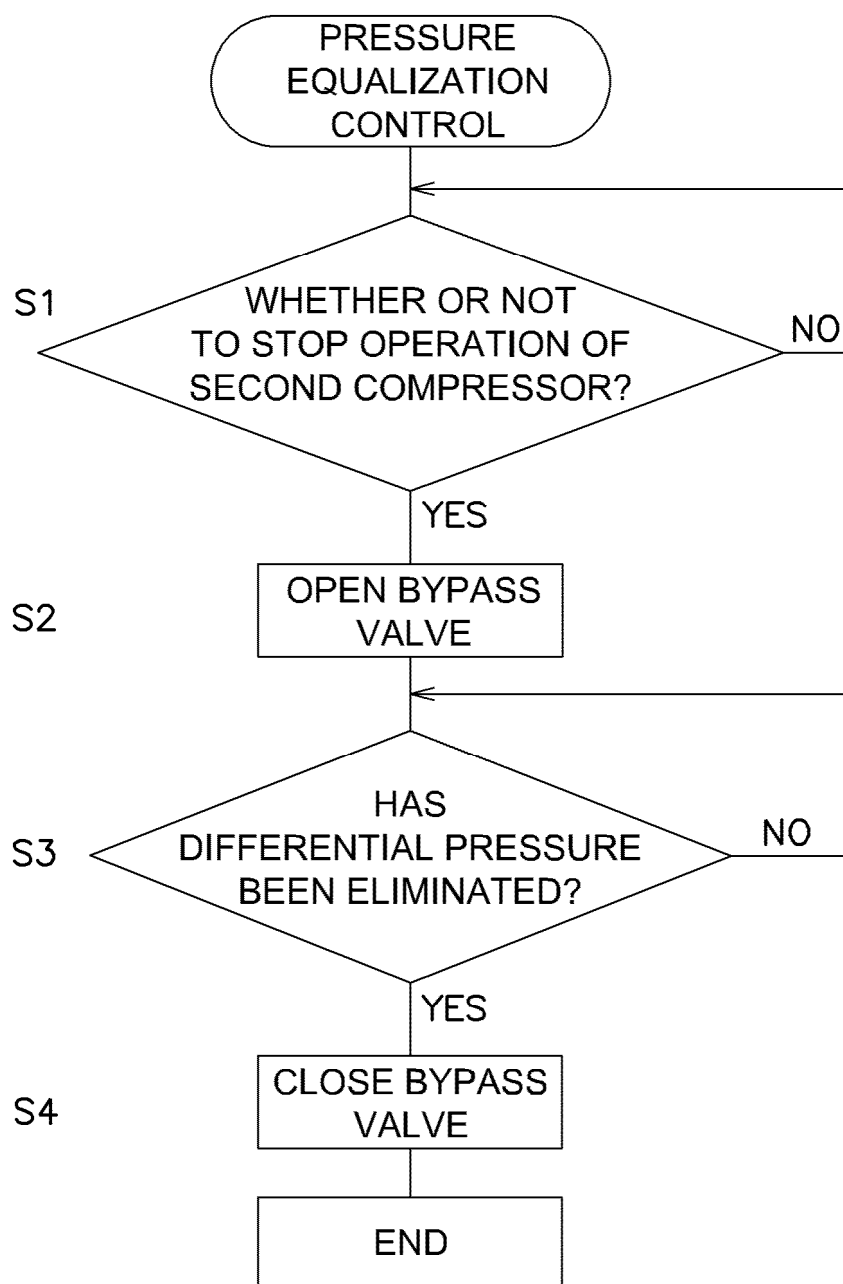
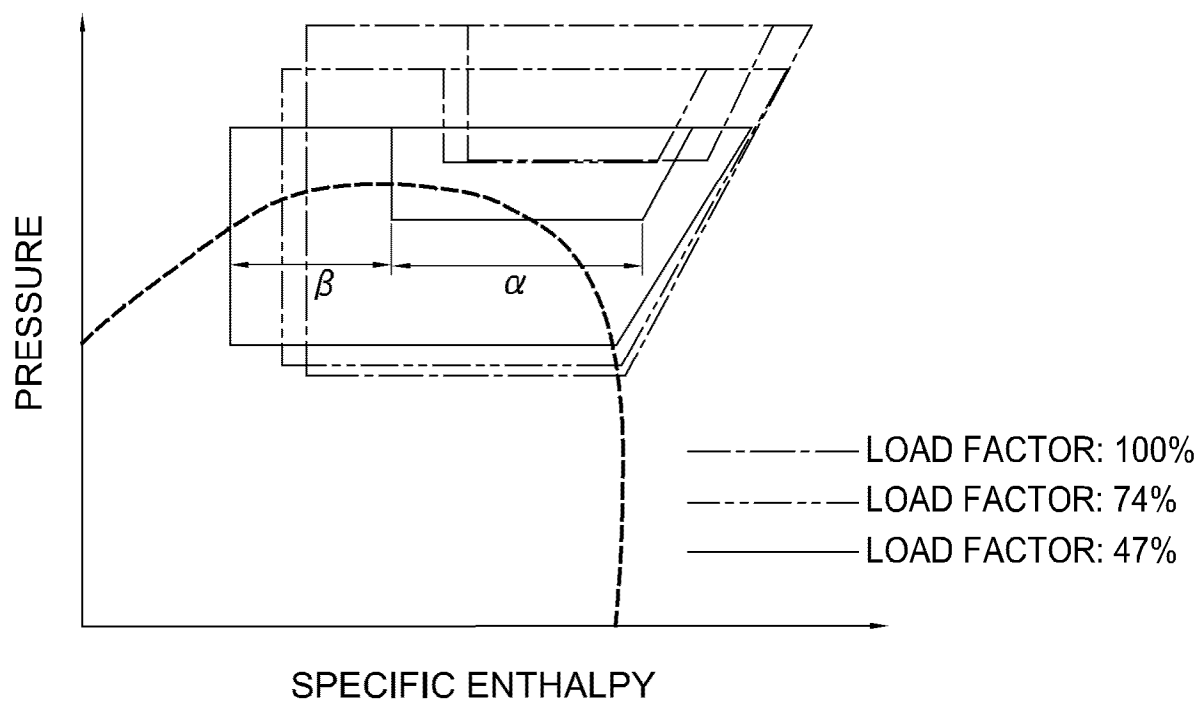
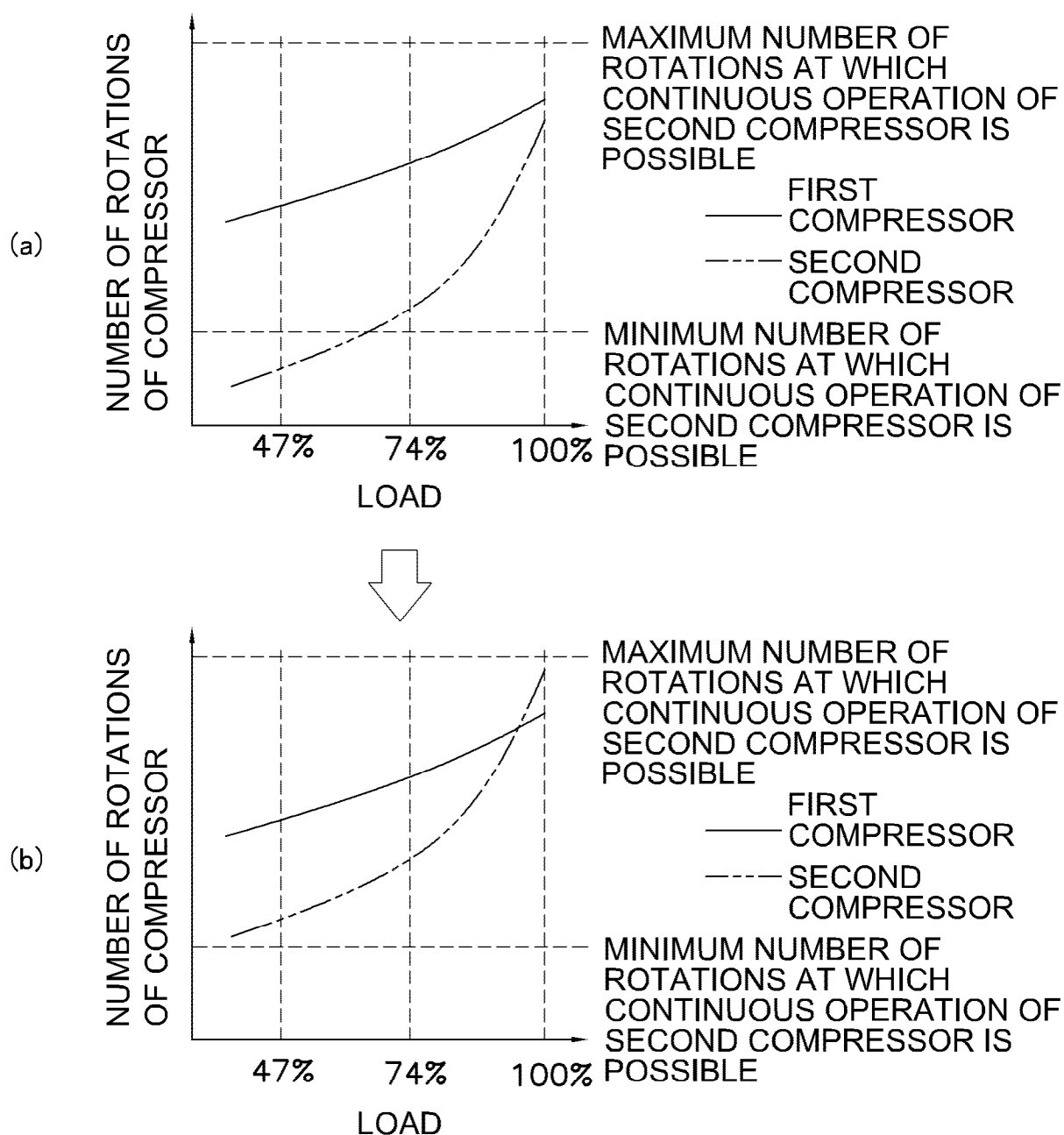


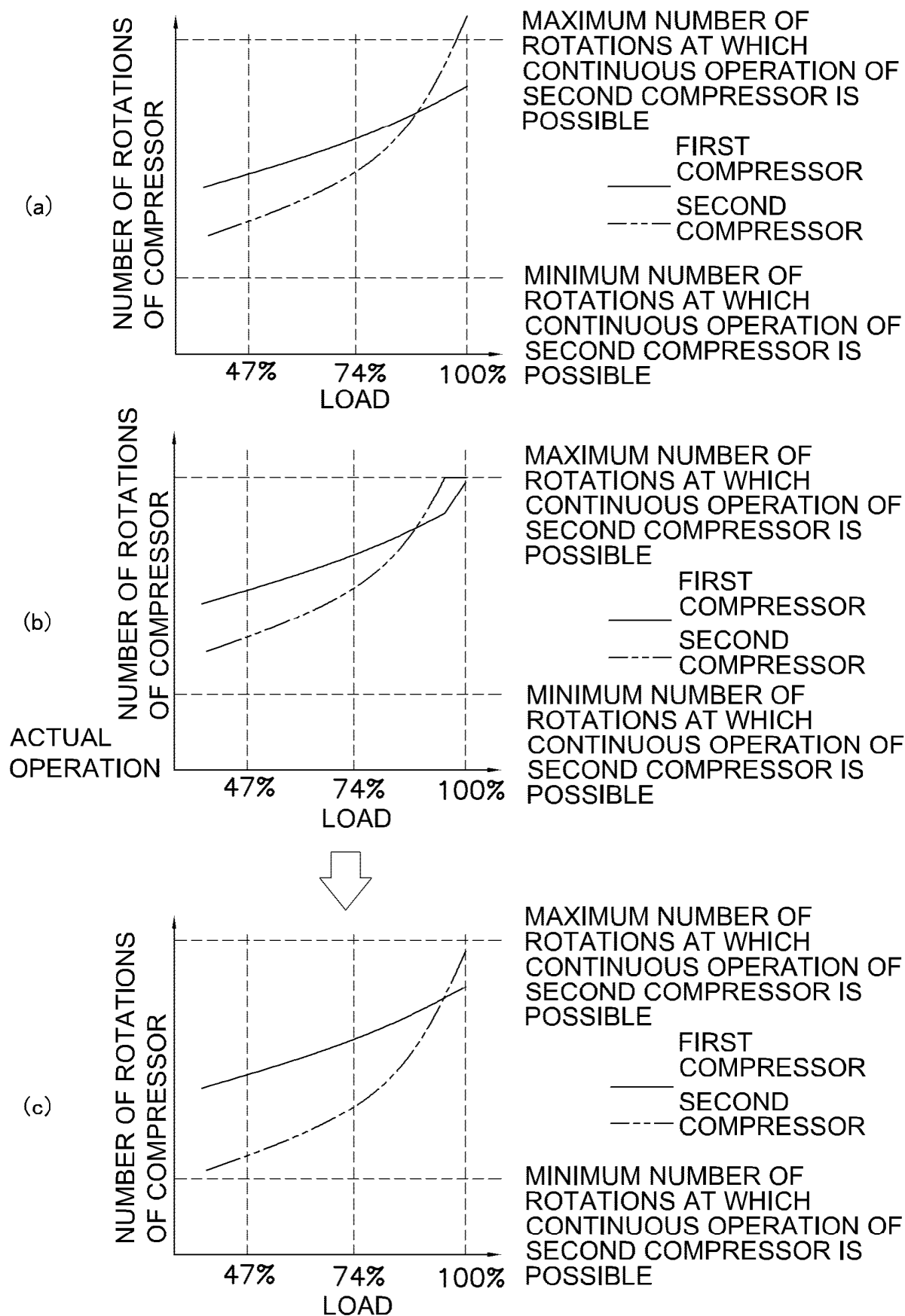
FIG. 4



β / α = CIRCULATION AMOUNT OF REFRIGERANT IN
 SECOND COMPRESSOR / CIRCULATION AMOUNT
 OF REFRIGERANT IN FIRST COMPRESSOR
 = REFRIGERANT CIRCULATION AMOUNT RATIO

FIG. 5





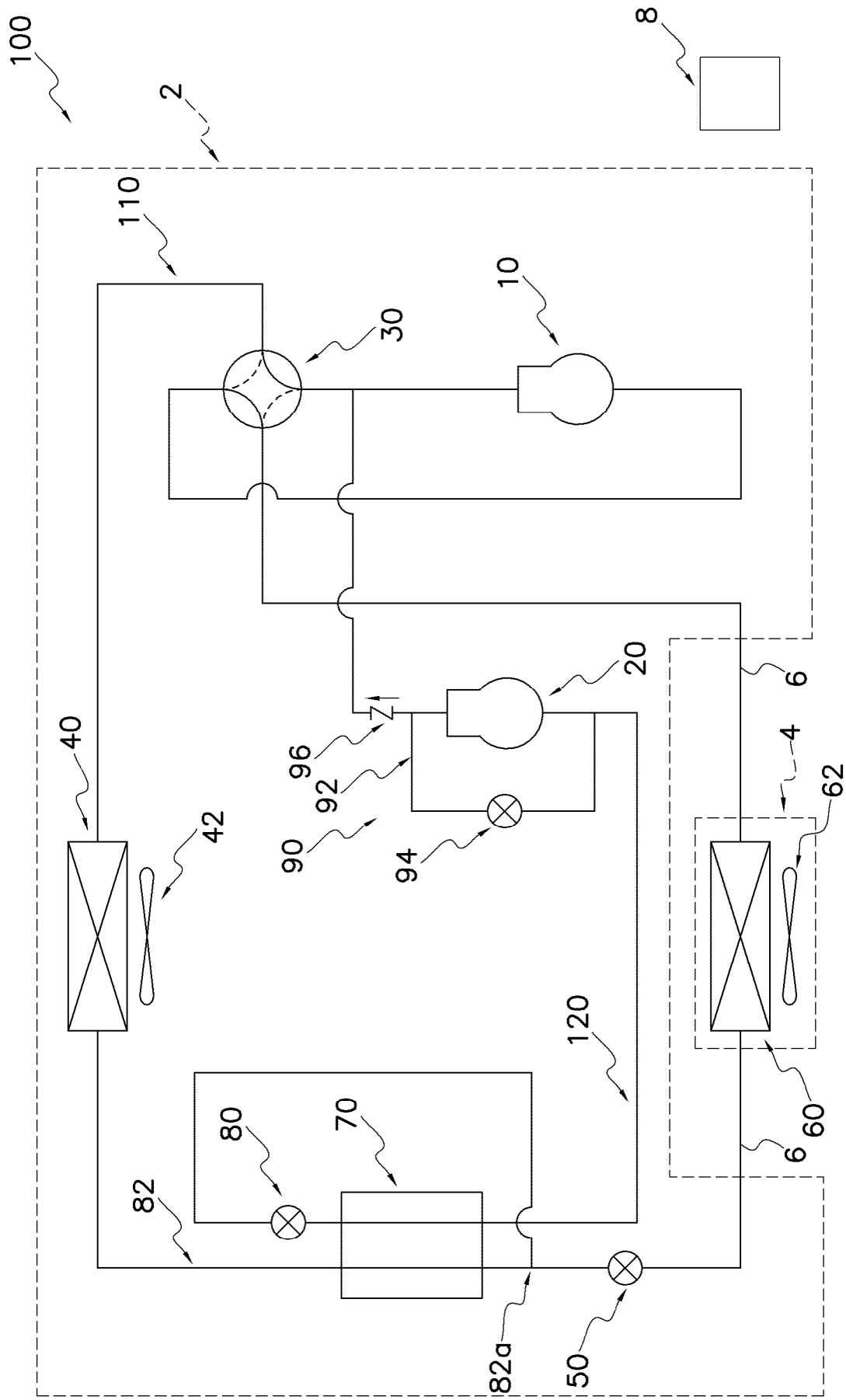


FIG. 8A

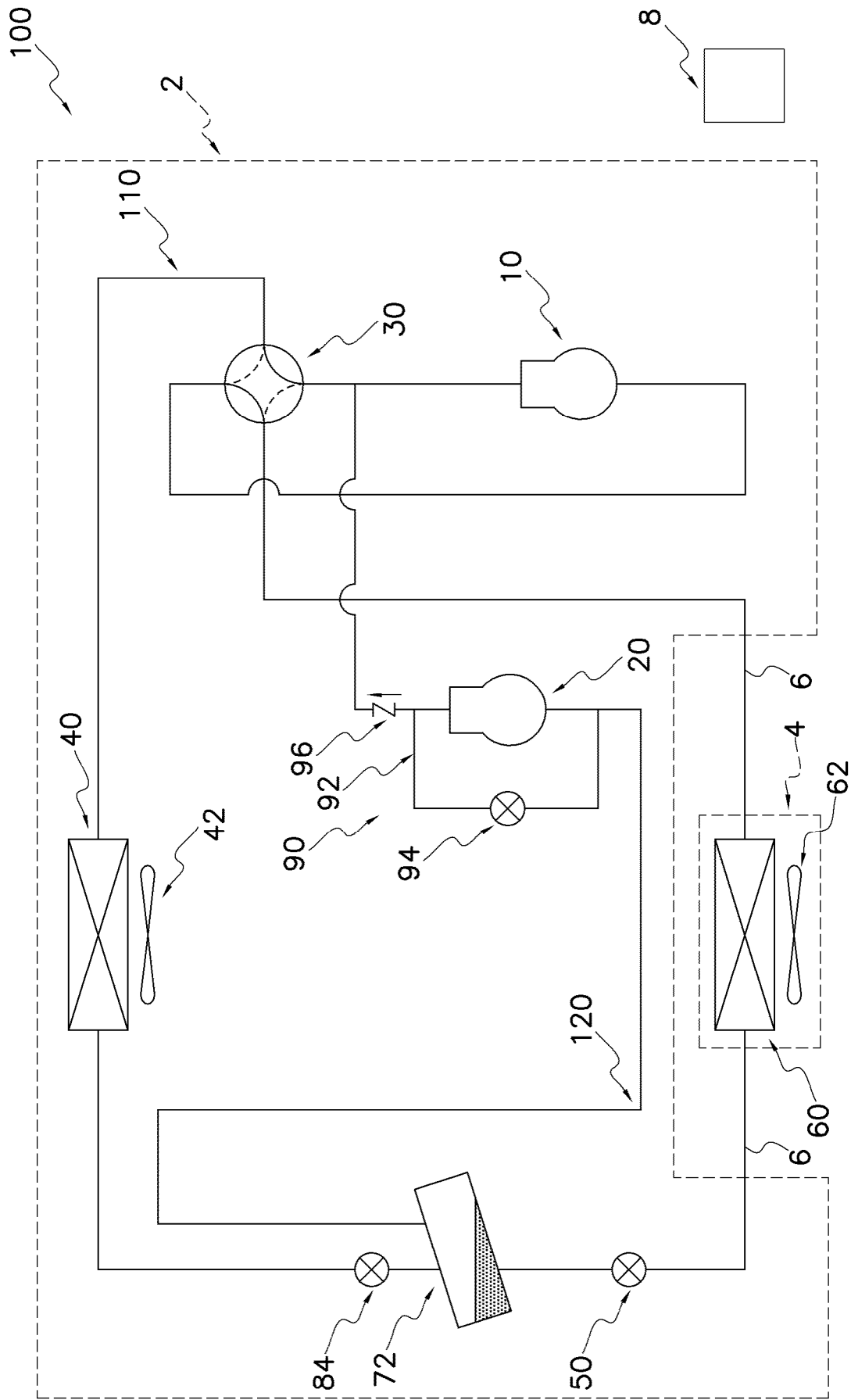


FIG. 8B

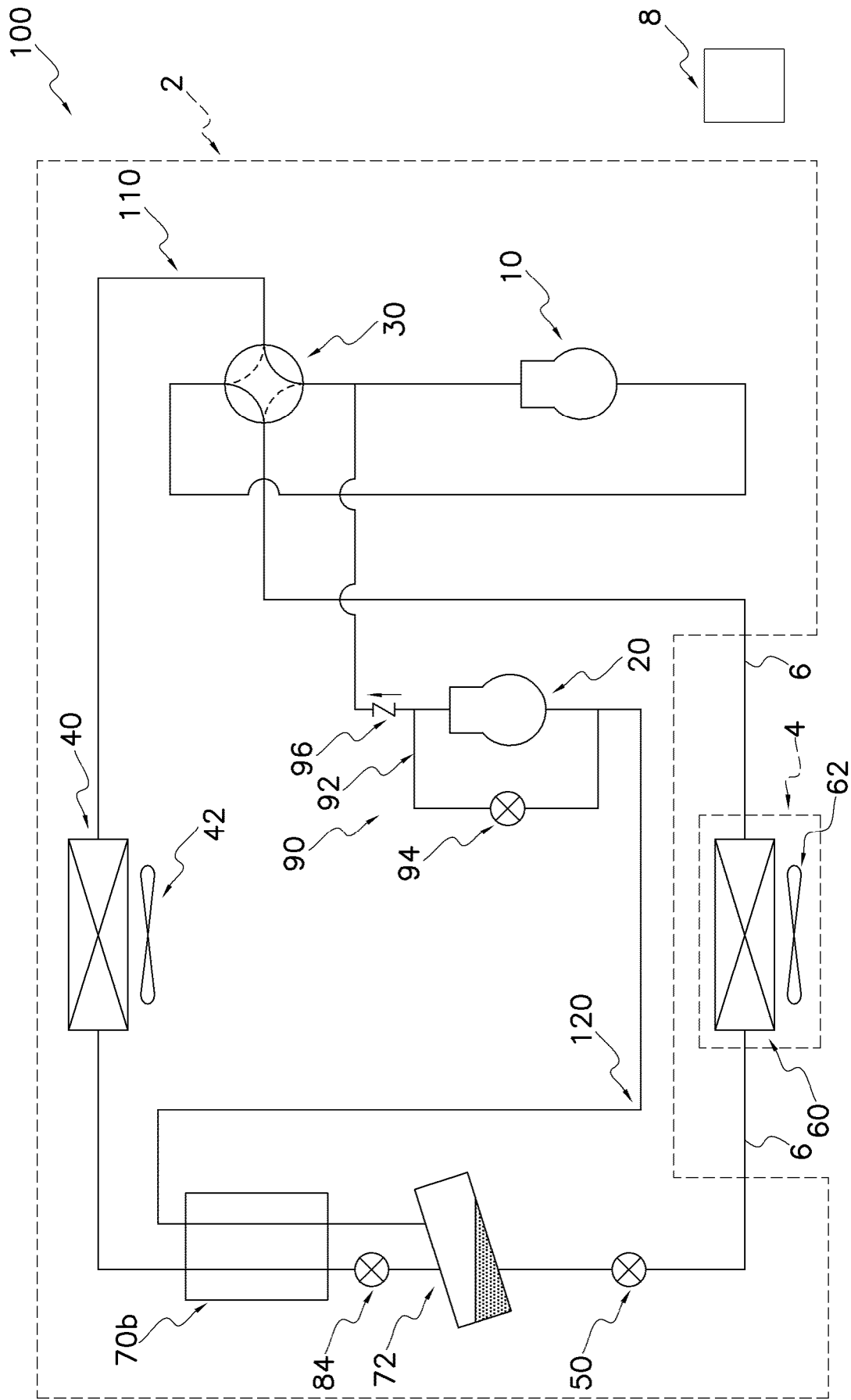


FIG. 8C

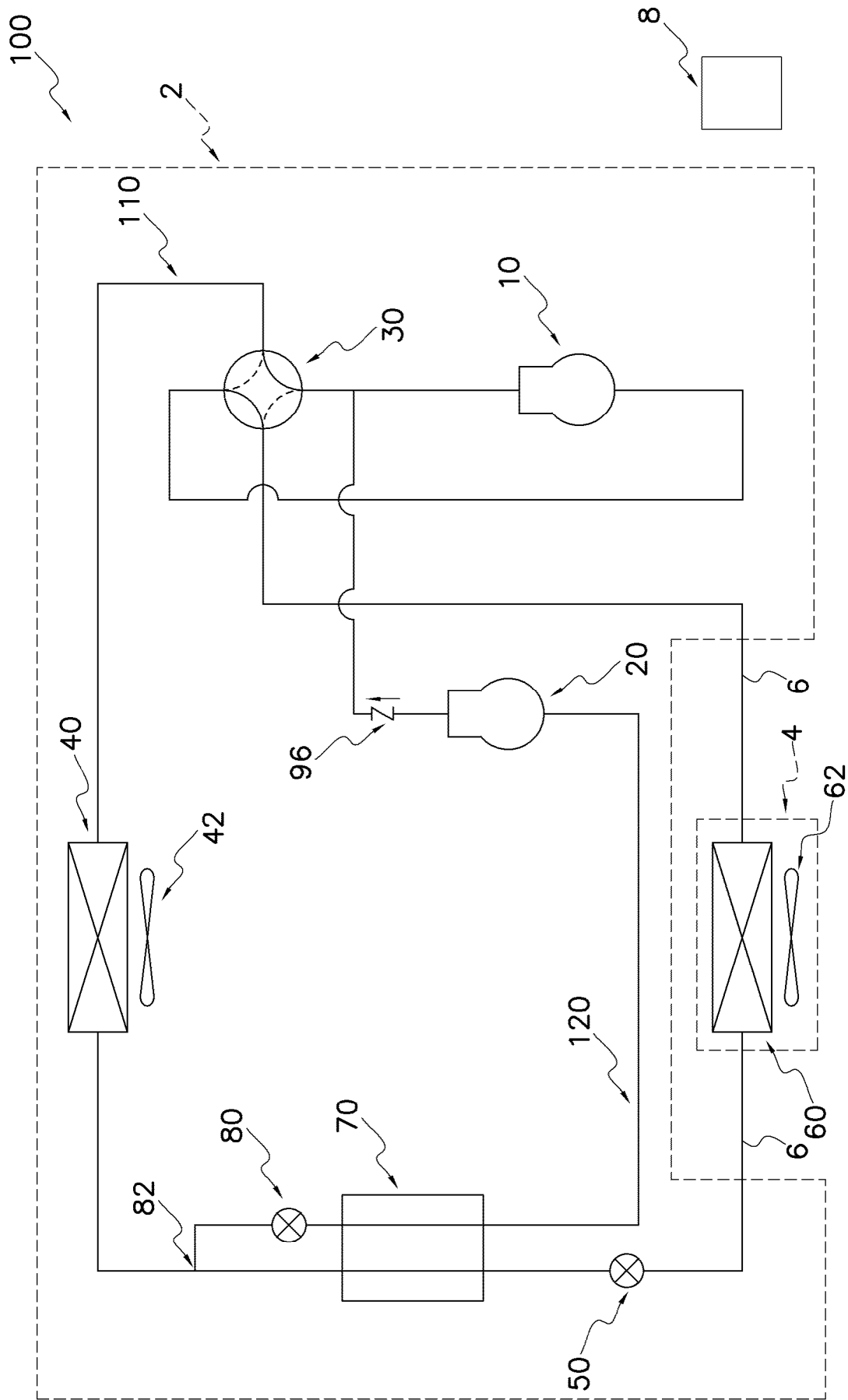


FIG. 9

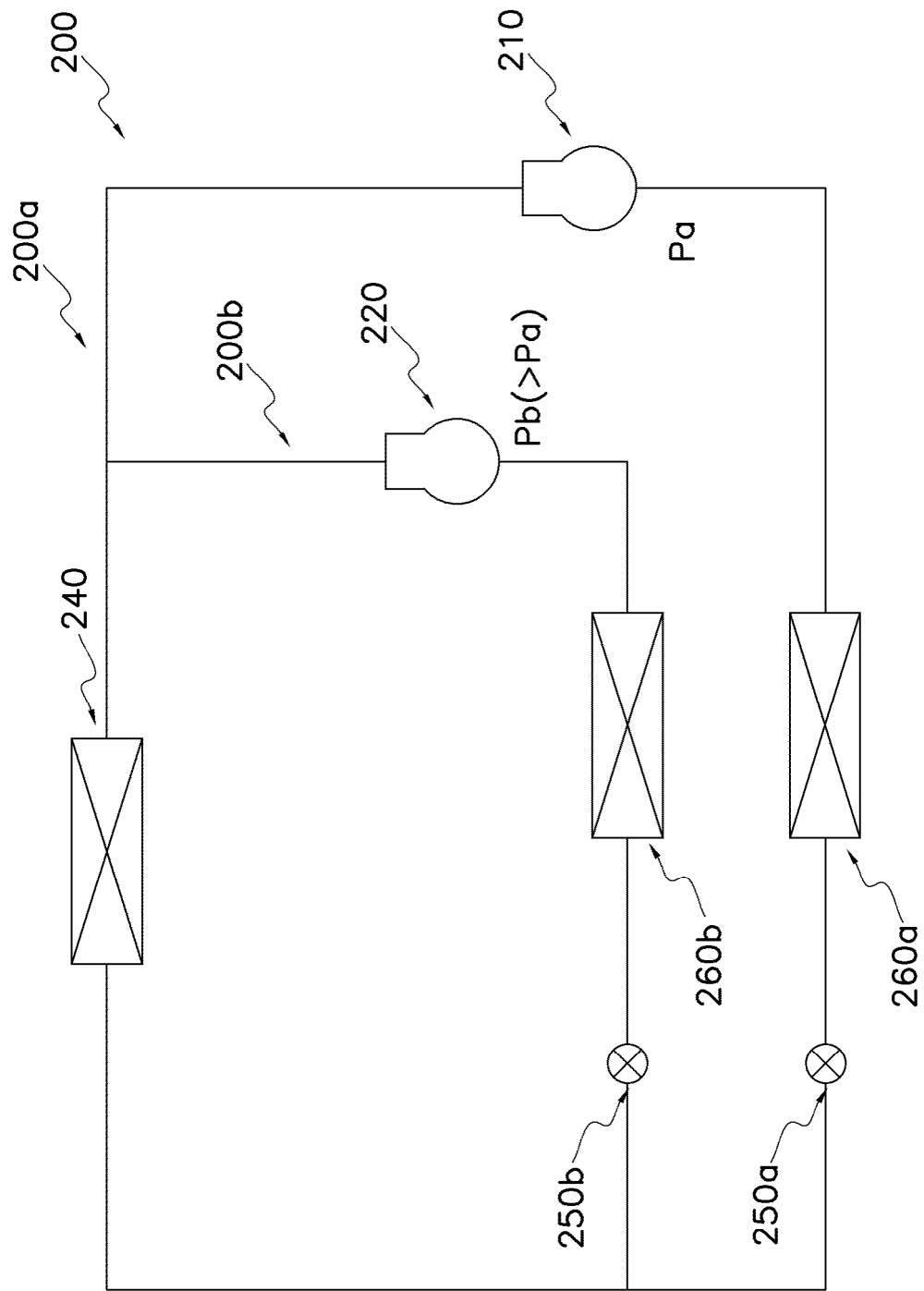


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2025/032054

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i; *F25B 1/04*(2006.01)i; *F25B 43/00*(2006.01)i

FI: F25B1/00 331F; F25B1/04 Y; F25B1/00 351E; F25B43/00 R; F25B1/00 396D; F25B1/00 361J; F25B1/04 A

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00; F25B1/04; F25B43/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2025

Registered utility model specifications of Japan 1996-2025

Published registered utility model applications of Japan 1994-2025

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/137401 A1 (MITSUBISHI ELECTRIC CORPORATION) 02 December 2010 (2010-12-02) paragraphs [0044]-[0046], fig. 1	1-3
Y		4-12
Y	JP 2008-96095 A (DAIKIN INDUSTRIES, LTD.) 24 April 2008 (2008-04-24) fig. 4	4-12
Y	WO 2009/096179 A1 (DAIKIN INDUSTRIES, LTD.) 06 August 2009 (2009-08-06) fig. 5-7	4-12
Y	JP 2009-539058 A (CARRIER CORP.) 12 November 2009 (2009-11-12) paragraph [0003]	8-12
Y	JP 2007-147227 A (DAIKIN INDUSTRIES, LTD.) 14 June 2007 (2007-06-14) fig. 1-3, 5-6	12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

24 September 2025

Date of mailing of the international search report

11 November 2025

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)

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Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2025/032054

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JP	2008-96095	A	24 April 2008	(Family: none)	
WO	2009/096179	A1	06 August 2009	(Family: none)	
JP	2009-539058	A	12 November 2009	US 2009/0175748 A1 paragraph [0003]	
JP	2007-147227	A	14 June 2007	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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